Vol. VI. *May, 1904.* *No. 6*

BIOLOGICAL BULLETIN

A CRUSTACEAN-EATING ANT (LEPTOGENYS ELONGATA BUCKLEY).

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There are few more profitable fields for the comparative study of instinct than the larger genera of the social Hymenoptera. This is especially true of the larger genera of ants, such as *Camponotus*, *Formica*, *Myrmecocystus*, *Leptothorax*, *Pheidole*, *Atta* and *Crematogaster*. To these genera, each of which embraces species presenting a considerable range of ethological peculiarities while differing but little in morphological characters, we must also add *Leptogenys*, with its subgenus *Lobopelta*, a rather large tropicopolitan congeries of species belonging to the primitive Ponerine subfamily.[1]

Only a single member of this genus, *Leptogenys* (*Lobopelta*) *elongata* Buckley, is known to occur north of the Rio Grande River. It is not uncommon in the semiarid regions of Central Texas (Travis and Comal counties) and has been taken even as far north as Colorado and the District of Columbia. Frequent observations during the past three years have enabled me to confirm and extend my former account of the habits of this very interesting ant.[2]

I am now able to state positively that the peculiar apterous females, indistinguishable from the workers except for the shorter and more rounded petiolar node and the more voluminous gaster, are the only females produced in the colonies of *L. elongata*. Each colony contains only a single one of these females and no other is tolerated in the nest. Even the young virgin females leave the formicary very soon after hatching and acquiring their

[1] *Lobopelta* differs from *Leptogenys sensu stricto* in having broader mandibles which, when closed, leave little or no space between their inner borders and the anterior margin of the clypeus.

[2] "A Study of Some Texan Ponerinæ," BIOL. BULL., Vol. II., No. 1, Oct., 1900.

red adult coloration. There can, of course, be no true nuptial flight, since the females are wingless. Most conclusive evidence in regard of the nature of these females has been furnished by my former pupil, Miss Margaret Holliday,[1] who found them to possess not only well-developed ovaries but a typical receptaculum seminis. It is interesting to note that the slight morphological differences separating these females from the workers are still further diminished by Miss Holliday's discovery that the latter have as many ovarian tubules as the former and may occasionally possess a receptaculum.

That the numerous tropical species of *Leptogenys* agree with the Texan species in having very ergatoid females, is indicated, first by the fact that no winged *Leptogenys* females have been seen, though many species of the genus have been known for years, and secondly by Wroughton's observations on the Indian *Leptogenys diminuta* Smith, recorded by Forel:[2] "At my request Mr. Wroughton has excavated an enormous formicary of *L. diminuta* to a considerable depth, but has looked in vain for a female among the many thousands of workers. All he could find was a worker whose abdomen was conspicuously distended with the ovaries. This worker differed in absolutely no particular from the others, and there is nothing very extraordinary even about its abdomen. This result would seem to confirm Emery's opinion."[3]

In my paper on the Texan Ponerinæ I failed to furnish conclusive proof of the identity of the males of *L. elongata*, as up to that time I had not taken this sex in the formicaries. More recently I have repeatedly seen the males in the natural nests and have bred them from larvæ and cocoons in captivity. They are of a rich yellow color, retaining throughout life the tint exhibited by the workers and females only during their callow stages. Even when quite mature the males are seized by the workers, when-

[1] "A Study of Some Ergatogynic Ants," *Zool. Jahrb. Abth. f. Syst.*, Bd. XIX., Heft 4, 1903, pp. 295–297.

[2] "Les Formicides de l'Empire des Indes et de Ceylan," Part VII., *Journ. Bombay Nat. Hist. Soc.*, Vol. XIII., p. 312.

[3] Emery advanced the opinion that in the genus *Leptogenys* the function of the females may have been usurped by the workers. This is not strictly true, at least in *L. elongata*, since the petiole of the female is clearly different from that of the worker, as it is in the winged females of many other species of Ponerinæ.

ever the nest is disturbed, and carried away like the very slender larvæ and cocoons, with their bodies tucked away between the legs of the workers. The males leave the nests at night, like the peculiar males of *Eciton* — another genus in which the females are apterous — and are often lured into the houses by the electric lights during the late spring and early summer months, especially during the latter part of May and early June. It would be extremely interesting to learn something of the mating habits of these highly heliotactic males and wingless females. Do the males, during the breeding season, seek out and enter strange nests of their own species in order to fecundate the virgin females? This seems improbable when we stop to consider that male ants are so very stupid that they are unable to find their way back to their parental nest when once they have strayed away from it. Are the wingless females fecundated by the males of the same colony, *i. e.*, by the offspring of the same mother? This is possible but improbable, since this would be a flagrant case of inbreeding. It seems more likely that the virgin females leave the parental nest and wander about as pedestrians, till they are found and fecundated by the winged males, as in the case of the Mutillidæ. The same problems and answers seem to be suggested by the large winged males and dichthadiiform females of *Eciton* and *Dorylus*.

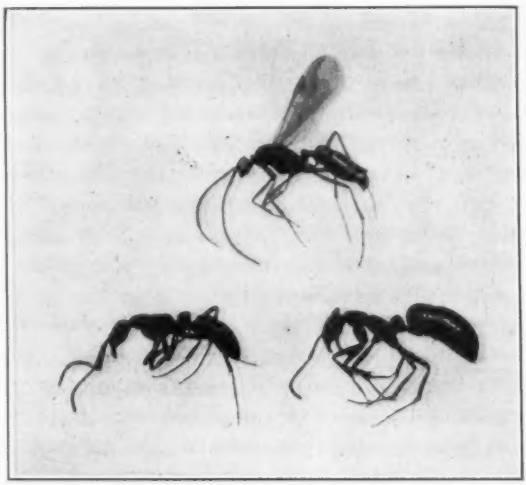
My former paper contained no account of the feeding habits of *L. elongata* in a state of nature. In my artificial nests the insects and their larvæ were fed on termites. I have since found that these ants, under natural conditions, feed very largely, if not exclusively on the common wood-slaters (*Oniscus* and *Armadillidium*) which abound under stones and logs in the shady places where the formicaries are excavated. I have repeatedly seen workers of *L. elongata* returning to their nests, carrying dead slaters in their mandibles. The earth surrounding the entrances to the nests is invariably white with innumerable bleaching limbs and segments of the crustaceans, showing that great numbers of these animals must be habitually destroyed by the ants. Their long, toothless mandibles resemble scissors and seem to be admirably adapted for cutting through the intersegmental membranes of their prey and exposing the

edible parts. *L. elongata* is, to my knowledge, the only ant known to feed on crustaceans as a regular diet. Other ants are either insectivorous, granivorous, mycetophagous, or collectors of the saccharine exudations or juices of insects and plants.

The little that is known concerning the habits of other species of *Leptogenys* would indicate that the North American form is peculiar in the character of its food. Wroughton has studied the habits of two of the Indian species of *Lobopelta*, *L. distinguenda* Emery and *L. chinensis* Mayr.[1] Concerning the former he writes as follows: "This species is fairly common from Poona westwards to the Ghats. The idea of a disciplined army has been fairly developed in this genus. *L. distinguenda* may sometimes, it is true, be found loafing about singly, but these individuals are probably only scouts; ordinarily, she is only met, in the early morning or late in the afternoon, travelling in an unbroken column four to six or eight abreast, straight, or rather by the easiest road, to the scene of operations. This is usually a colony of white ants whose galleries have been broken open by the hoof of a passing beast, or some similar accident. Arrived at destination, each worker seizes her termite prey, tucks it under her thorax in the orthodox ponerine fashion, and the column then returns (but marching 'at ease' and much less regularly than on the outward journey) to the nest. I have never succeeded in finding a nest; on one occasion I tracked a column for more than fifty paces, only to lose it in a patch of prickly pear. I do not think that *L. distinguenda*, any more than any other ant, ever has the inspiration to open a termite gallery for herself; on the occasion mentioned above, the column passed close to several, and even over one colony of white ants before reaching its destination; I believe, however, I saw a worker break open a piece of tunnel, into which a termite had retreated, but cannot be sure, and the practice certainly was not general. Nor are the termites followed into the galleries, partly, perhaps, because the passage is too small for a *Lobopelta*, but equally, I imagine, because such a measure would be very like 'drawing' a badger 'only more so.' Mr. Aitken tells me he has seen 'hundreds going into a hole in the ground and emerging with white ants,' but this is very different from entering a termite gallery."

[1] "Our Ants," *Journ. Bombay Nat. Hist. Soc.*, 1892, p. 56–58.

Concerning *L. chinensis* Wroughton makes the following statements: "This species is even commoner than the last. *Distinguenda* would seem to be a denizen of forests, while *Chinensis* prefers more open and inhabited country. I have only once seen *Chinensis* on the warpath, and then the objective, a large worm, in several pieces, had been reached, and the column was on its way home. The column I must say was more a mob than a disciplined army, but this may have been due to the fact that the normal irregularity of the homeward march was enhanced by the size and shape of the booty, which did not admit



Leptogenys (*Lobopelta*) *elongata* Buckley, male, female and worker.

of being carried 'according to the regulations.' On the other hand, I have often, during the early part of the rains, witnessed a migration (or was it a colonization, in no case was a female, even apterous, present?) when the discipline and regularity of the column left nothing to be desired. My experience seems to show that *Chinensis* prefers a formation in fours, at any rate when carrying her own larvæ and pupæ. Mr. Aitken has furnished me with the following most interesting note on *Chinensis*. 'There is a populous community of this ant, in a hole, in the

foundations of my house, at Goa. From the nest there is a well marked "road," crossing a broad gravel path, and then ramifying all over the tennis ground. They issue after sunset, and march along one of the main branches, or break up into parties and take different routes. When they come to a place where the termites have thrown up new earthworks, and are busy eating the dead grass underneath, they collect in dense masses, waiting for an opportunity of breaking in, which they very likely find when the termites attempt to extend their works on any side. Then the slaughter begins. Sometimes the poor termites are killed far faster than they can be carried off; and on one occasion, as late as 7 a. m., I saw the ground still heaped with slain, and an unbroken stream of ants, fifty-six yards long, carrying them away. Each ant had two or three in her jaws. If these ants cross the grounds of a community of 'harvesters' (*? Holcomyrmex*) after the latter are up in the morning, they have to flee in their turn. A *Lobopelta*, when once a worker major has laid hold of her by the leg, appears to be perfectly helpless, she can neither kill her enemy nor shake her off. Sometimes another *Lobopelta* will come to her assistance, and, after vainly trying to tear off the aggressor, will pick up her comrade and carry her and her enemy off together.'"

Apparently some of the American species of *Leptogenys* also prey on termites. The nest of a single colony of *L. Wheeleri* Forel which I observed at Cuernavaca, Mexico, was almost embedded in a *Eutermes* nest, and I have no doubt that the ants were in the habit of using their neighbors as a convenient larder.

The only other *Leptogenys* of which I find the habits recorded is *Lobopelta diminuta* Smith var. *bismarckensis* Forel from the Bismarck Archipelago. Dahl[1] compares this species with the amazon ant (*Polyergus rufescens* of Europe and North America), on account of the sickle-shaped, toothless mandibles. He says: "Although I have drawn a comparison between *Leptogenys bismarckensis* and *Polyergus rufescens*, I must clearly emphasize the fact that I never found the nest of the former species and

[1] "Das Leben der Ameisen im Bismarck-Archipel, nach eigenen Beobachtungen vergleichend dargestellt," Berlin, R. Friedländer und Sohn, 1901, p. 52.

could not, therefore, observe whether the work of the colony is carried on by slaves. What firmly convinced me, nevertheless, that this species is a slave-holding ant, was the following: The mandibles are long and sickle-shaped, almost as much so as in our German slave-holders, and little adapted for working, as they have no masticatory border. They could of course, be of use in killing termites, as Forel supposes to be the case in this genus, but the place were I found the species under consideration was far removed from all termite nests. It was on the sea-shore between blocks of coral, where I saw about fifty individuals in a troop, as it were, on the march. It was evident that the troop had left the nest for the purpose of perpetrating a robbery in common. That this robbery, after what has been said, was for the purpose of obtaining slaves, seems probable." I venture to maintain that Dahl is mistaken in supposing that *L. bismarckensis* is a dulotic ant, as a perusal of the above quoted passages from Wroughton's work will suffice to show.

It is also evident from the observations of Wroughton and Aitken that the Indian species of *Leptogenys* differ widely in habit from *L. elongata*. The colonies of the latter species are very small, rarely containing more than a hundred individuals, whereas the colonies of the Indian species appear to contain thousands of workers. Moreover, the workers of *L. elongata* leave the nest singly and hunt about timidly for their phlegmatic and defenceless prey, whereas the Indian species hunt in well organized files somewhat after the manner of the driver ants and ants of visitation (*Dorylus* and *Eciton*). And such diversity of instinct is exhibited not only in the same genus but within the confines of the same subgenus (*Lobopelta*).

In conclusion I give the synonymy and a description of all three phases of the North American *Leptogenys*.

LEPTOGENYS (LOBOPELTA) ELONGATA (Buckley) Wheeler.

Ponera elongata Buckley, Proc. Ent. Soc. Phila., Vol. VI., 1866–67, p. 172, ♀.

? Ponera texana Buckley, ibid., p. 170, ♀.

Lobopelta septentrionalis Mayr., Verhandl. k. k. zool. bot. Ges. Wien, Bd 36, 1886, pp. 438, 439, ♀.

Leptogenys septentrionalis Emery, Zool. Jahrb. Abth. f. Syst., Bd. 8, 1894, p. 268, ♀.

Leptogenys (*Lobopelta*) *elongata* (Buckley) Wheeler, Biol. Bull., Vol. II., No. 1, Oct., 1900, p. 2, 7, Fig. 4. ☿ ♀ ♂; Trans. Tex. Acad. Sci., Vol. IV., Pt. II., No. 2, 1902, p. 9.

WORKER. — Length 5–6.5 mm.

Head slender, excluding the mandibles, longer than broad, somewhat broader in front than behind. Eyes moderate, flattened, situated a little in front of the middle of the sides of the head. Mandibles slender, nearly two thirds as long as the head, gradually increasing in breadth as far as their apical third, forming a sharp, toothless blade and thence narrowing more suddenly to the acute, curved tip. Clypeus prolonged forward in the middle to a rather acute point and with a prominent median keel; lateral emarginations distinct but not very deep. Frontal furrow extending back a little beyond a line connecting the posterior orbits of the two eyes. Antennæ slender; scapes extending about one third their length beyond the posterior corner of the head. First and third funicular joints subequal, decidedly shorter than the second joint; joints 4–11 subequal, shorter than joints 1 and 3. Thorax elongate, its dorsal surface horizontal, meso- and epinotal regions laterally compressed; depression behind the small mesonotum short but rather deep. Basal surface of epinotum twice as long as the sloping declivity, which is somewhat flattened and transversely marginate below and behind. Petiole in profile as high as the thorax, somewhat higher behind than in front and nearly as long as high; anterior, dorsal and posterior surfaces flattened; the dorsal and posterior meeting at a somewhat sharper angle than the anterior and dorsal surfaces. There is a distinct tooth at the anterior, ventral border of the petiole. Seen from above this segment is pyriform, twice as broad behind as in front, with flattened sides and rounded dorsal surface. Gaster slender, somewhat deeper than the petiole, distinctly constricted between the first and second segments. Sting prominent. Legs long and slender; claws with long pectination.

Mandibles smooth and shining, the former with a few scattered punctures and faint traces of striation; the latter thin and submembranaceous along its anterior border and obliquely rugose on the sides. Head, thorax and petiole subopaque, rather densely and uniformly covered with shallow punctures. Region between the eyes and clypeus longitudinally rugose. Gaster shining, very sparsely and finely punctate.

Body and appendages clothed with delicate, grayish yellow pubescence; the head, thorax and abdomen also with sparse, grayish yellow hairs, which are long and projecting on the clypeus and terminal segments of the gaster.

Deep red; edges of mandibles and thoracic sutures somewhat blackened. Antennæ and legs a little paler than the trunk; tip of gaster, sting, anterior border of the clypeus and the spines of the tibiæ, yellow.

FEMALE. — Length 6.5–8 mm.

Apterous and decidedly ergatoid in form, indistinguishable from the

worker in the head and thorax, even lacking ocelli and with eyes no larger than those of the worker. The petiole is proportionally shorter and higher, so that when seen from above, it is little if any longer than broad behind, shaped like an eqilateral triangle with rounded angles. In some females the upper surface of the segment in profile is flattened like that of the worker, but in most cases it is more convex and in this respect somewhat like the petiole of the male. Gaster conspicuously larger, both broader and higher than that of the worker. Sting like that of the worker.

MALE. — Length 5.5–6.5 mm.

Head, including the very prominent, somewhat reniform eyes, distinctly broader than long; cheeks and postocular regions very short, ocelli large and protruding. Mandibles small, hardly meeting with their tips, slightly geniculate, broadest at the base and suddenly tapering to a slender point. Clypeus less produced, less pointed in front and with a blunter keel than in the worker. Antennæ long and filiform, 13-jointed; joints 3–13 long and cylindrical, subequal; scape very short, hardly a third as long as the third and succeeding joints; second joint very small, somewhat narrower than the scape and hardly longer than broad. Thorax rather robust, with prominent Mayrian furrows on the mesonotum; epinotum long and sloping. Petiole small, hardly half as high as the first gastric segment, about as high as long, in profile rounded above, with sloping anterior and posterior surfaces; seen from above it is oblong, a little longer than broad, hardly wider behind than in front. Gaster with well developed constriction between the first and second segments and large, cultriform, exserted genital appendages, which are fully half as long as the remainder of the gaster. Legs long and slender.

Smooth and shining, except the antennæ, which are opaque. Surface of thorax indistinctly and finely punctate.

Body covered with yellowish hairs, which are long and prominent on the gaster, shorter on the head and thorax, and still shorter and denser, and more like pubescence, on the appendages.

Body and legs light yellow throughout. First and second antennal joints yellow, remaining joints brown. Wings grayish hyaline with brownish veins and stigma.

Type Locality. — Austin, Texas.

Other Localities. — District of Columbia (Pergande, Mayr); Colorado (Cresson, Emery); New Braunfels and Belton, Texas (Wheeler).

THE MARCHING OF THE LARVA OF THE MAIA MOTH, HEMILEUCA MAIA.

WM. S. MARSHALL.

In the autumn of 1901 while collecting along the marshy shore of Lake Wingra, near Madison, I noticed many specimens of the maia- or buck-moth, *Hemileuca maia*, flying low over the marsh. Both males and females were present, and many of the latter, having settled, were laying their eggs on the grass. These were placed in a somewhat irregular set of spirals closely packed together so that when they hardened, the grass could often be pulled away leaving the eggs stuck together and forming a short tube. The process of oviposition and the arrangement of the eggs has been described by Riley[1] and copied by Packard.[2]

Without having any definite plans in view I collected a great many of the eggs most of which I put in a cold place, but a few I left in an open bottle in my room. One morning I noticed on the neck of this bottle a black mass which was found to be a group of young caterpillars; they had evidently hatched but a short time before. Later in the morning I again looked at the eggs and found that more had hatched; all in the first bunch, having in the meantime left the bottle, were marching in a line on the table. Again, later in the day other groups were seen, and in nearly every instance, each group had formed a line marching in a regular procession and following the leader whichever way he turned. I placed some large sheets of paper on the table; upon these the different groups were soon marching, and could be much more easily seen than when upon the darker table. I now, with a pencil, knocked the leader away from one line and was surprised to see the next in the line, now the leader, stop when he reached the place occupied by the first leader prior to his removal. Here he stopped and raising himself upon his prolegs moved the anterior part of his body to and fro as if he

[1] Riley, C. V., "Fifth Missouri Report," p. 128.

[2] Packard, A. S., "Insects Injurious to Forest and Shade Trees," Washington, 1890.

were trying to scent the leader. He soon discontinued this and resumed his natural position again, appearing, however, for some time, very restless. While this had been going on, the rest of the caterpillars had crowded up to the front one; they appeared for some time very restless, but finally settled in a close bunch, in which position they all remained: one here and one there would often become restless for a few minutes, but end by settling again in its former position in the bunch. I now marked the original leader (he had been kept away from the others all of this time) by putting a little white paint on his back and then picking him up on a small piece of paper dropped him back at the edge of the group. The leader, in the meantime, had been walking around evidently seeking the other caterpillars, and when he returned to the bunch, began to walk restlessly around near its edge. In a few minutes he started off away from the others and these began to follow him, moving in a regular procession.

Different masses of the eggs were now brought into my room, a few each week, and when the caterpillars hatched, a few experiments were carried on to see if the removal of the leader always affected the followers in the same way, and if a new caterpillar would not assume the leadership and be followed by the rest. The results I have thought it best to write out briefly and not to arrange them in a tabulated form. The first set contains those in which the old leader, upon being returned to the bunch, resumed command, and the second lot, those experiments in which a new caterpillar became the leader. There then follow a few experiments differing from those contained in the first two lots. When the number of caterpillars forming the line was counted, this is given; but in some cases, however, the number which formed the line was not noted.

In nearly every instance the removal of the leader brought about at first the same result. When I removed him I would draw a line on the paper marking a place where his head was before removal. When the second caterpillar in the line reached this point, he always stopped, rarely crossing the line, and when the bunch was formed, it was always back of the line.

1. Sixty-four in line. 8:15, leader removed; 8:30, all bunched; 8:31, leader returned; 8:35, all restless; 9:00, leader started, and at 9:08, all were in line and moving.

2. Six in line. 8:45, leader removed, others soon bunched; 8:51, leader returned; 8:57, old leader started; others following.

3. 8:47, leader removed; 8:50, all bunched; 8:51, leader returned; he passed to back of bunch and started away, others following; 8:43, all in line.

4. Ten in line. 8:31, leader removed and all bunched one inch back of line; 8:36, leader returned; 8:55, leader starts and others follow.

5. 8:57, leader removed and put back at once, seventh in the line; all bunched; 4:06, P. M., leader started, others following.

6. 8:16, leader removed; 8:26, leader returned; 8:31, leader started, others following.

7. 8:21, leader removed; a caterpillar, the next in line, goes on half an inch and here they all bunch; 8:30, leader returned; 8:42, leader starts and others follow.

8. 2:32, leader removed; 2:47, leader returned to bunch; 3:55, leader started, others following.

9. One hundred and fifty in line. 10:22, leader removed; 10:40, bunched and leader returned; 11:25, leader started and others followed.

The following are experiments where a new leader started:

1. Forty in line. Leader removed; 9:10, bunched; 9:11, a caterpillar at back of bunch starts and others follow.

2. Twenty-one in line. 9:01, leader removed; 9:08, bunched; 9:10, one near front starts; 9:21, all in line following new leader.

3. Eighteen in line. 8:50, leader removed; in a minute the next caterpillar turned and started; 8:55, all in line and following new leader.

4. Thirty-six in line. 8:42, leader removed and the next caterpillar assumes leadership; 8:47, new leader removed and original one put back in middle of line; all bunch; and at 4:08, P. M., were still quiet.

5. Eighteen in line. 8:30, leader removed; 8:37, bunched; one went a short distance over the line but returned; leader returned; 8:46, new leader started and others follow.

6. Eleven in line. 8:38, leader removed; 8:41, next caterpillar returned along the line two inches and then came back; others bunched; 8:45, start with new leader.

7. Ten in line. 10:34, leader removed; line kept on; 10:39, second leader removed; march continued; 10:40, third leader removed; 10:42, bunched; 10:48, started with the original leader, who had been returned, at head.

8. 8:13, leader removed; 8:22, leader returned; 8:56, new leader started, others following.

9. 2:56, leader removed; 3:05, leader returned; 4:05, new leader started and others follow.

10. Forty-six in line. 9:24, leader removed; 9:33, all bunched; leader returned; 10:05, new leader starts and others follow.

11. One-hundred and twenty in line. 8:41, leader removed; when the entire line had bunched the leader was returned; 11:45, new leader starts and others follow.

12. One-hundred and fifty in line. 8:43, leader removed; 9:25, mostly bunched and leader returned; 10:10, old leader started, rest following; they went more than an inch and then returned to bunch again; 2:30, P. M., a new leader starts and others follow.

The following experiments were made by removing the leaders of two lines and then returning them each to the other's bunch:

A. Six in line. 2:02, leader removed; 2:06, bunched; leader of *A'* placed near head; 2:08, leader of *A'* starts and others follow.

A'. Thirty-two in line. 2:02, leader removed; 2:07, leader of *A* placed in bunch; 2:11, one, not the leader, started but returned; 2:35, leader of *A* starts and others follow.

B. Thirty-two in line. 1:56, leader removed, when others bunched leader of *B'* placed with them; 2:18, leader from *B'* starts and others follow.

B'. Thirty-five in line. 1:56 leader removed and leader of *B* placed in bunch; 2:03, leader of *B* starts and others follow.

C. 1.22, leader removed; 1:27, leader of *C'* placed in bunch; 3.20, line starts with entirely new leader.

C'. 1:22, leader removed; 1:27, leader of *C* placed in bunch. Called away and unable to follow this to end.

The following experiments I give separate from the others:

1. 8:24, leader removed; 8:33, leader returned and at once started out, the other caterpillars remaining in bunch; 8:38,

leader returned again; 8:42, he starts out again but none follow; in two minutes he returns to the bunch himself and starts a third time, this time some follow but soon return to bunch and leader goes off by himself.

2. Eighteen in line. 8:32, leader removed; 8:38, bunched; leader returned and they remained in bunch all morning.

3. Thirteen in line. Same thing happened as in number two.

In one lot, thirty-six in line, the leader had been marked and the line allowed to go on. The leader reached the last caterpillar in the line so that a circle was formed. They all kept moving, the leader finally reaching the place where he was when the circle was first formed; he then went half way around the circle and started off in another direction the others following.

From the above, it will be seen that the removal of the leader affects the whole line, but that he is not necessary for the further progression of the caterpillars. I have been unable to find references to the procession-caterpillar, but notice that the caterpillars of *Saturnia io*[1] march when young the same as the Maia-moth.

Dubois[2] notes that the procession-caterpillar spins a thread which the others in the line follow; the young larvæ of *Hemileuca* do the same, the thread being seen with a hand lens back of the line. In nearly all of the long lines, which the larvæ form, there is very apt to be at least one break where there is an inch or more between the nearest caterpillars, or such a break can be made by stopping one of the larvæ until the preceding ones have gone ahead for some distance: at such a place the thread also can be seen. When a break occurs, it does not in any way affect the movements of the line, the caterpillars following along the regular path.

Wishing to see how much the caterpillars depended upon this thread to enable them to follow in the exact path of the leader, I removed the thread a number of times when the distance between two neighboring caterpillars was great enough, and found that the course was not in the least altered. The caterpillars, upon reaching the end of the broken thread, generally kept straight on as if nothing had been done, failing to show a dependence

[1] Dickerson, Mary C., "Moths and Butterflies," 1901.

[2] Dubois, *Ann. Soc. Linn. Lyon.*, XLXI., 1900, p. 125.

upon the thread alone in following the path of those ahead. I next removed the thread, and then dipping a finger in water, rubbed it rapidly a number of times across the path and then wiped the place dry. When the first caterpillar reached this spot, he halted, and for three minutes remained at the same place, raising the anterior part of the body in the air acting the same as if the leader had been removed. At the end of this time he started forward following, as near as I could judge, the original path.

The following few experiments should have been made with the food plant of the caterpillar, but this being unobtainable at the time of the year when the caterpillars were hatching in my room, the leaf of the geranium, *Pelargonium*, which was easily obtained and possessed quite an odor, was used.

1. A small piece of the leaf was placed 5 mm. away from a small group which had been quiet for two or three hours; the caterpillars became at once restless and in two minutes, three had moved over and touched the leaf.

2. A small piece of the leaf was placed 5 mm. away from the leading caterpillars in a line; they became at once restless and "broke rank"; in four minutes two (not the leader) had reached the leaf.

3. A piece of leaf was placed 15 mm. from a group, nothing happened; the leaf was moved to 10 mm. and left for ten minutes, nothing occured; moved to distance of 5 mm. from caterpillars and all still remained quiet. I now moved the leaf to 3 mm. away, one immediately came out, touched the leaf and returned to its original position, in thirty seconds another came out, touched the leaf and returned.

4. A piece of leaf was placed 5 mm. from group, two came out, touched it and returned.

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Madison, February, 1904.

FORM-REGULATION IN CERIANTHUS, IV.

The Rôle of Water-pressure in Regeneration.

C. M. CHILD.

Introductory.

The regeneration of the marginal tentacles in cylindrical pieces was described in the first paper of this series (Child, '03*a*).

The tentacles do not arise from the new tissue closing the end, nor from the cut surface, but from the old body-wall itself, which first becomes thinner and loses its muscular layer in the region where the tentacles are to appear and then gives rise to small buds, corresponding in number and position to the intermesenterial chambers.

The fact that the new marginal tentacles arise some distance away from the cut surface by a local transformation of the already differentiated body-wall is of considerable importance. There must be some adequate ground for the localization of this peculiar process of transformation in a region of the body-wall which apparently differed in no way from adjacent parts before the cut was made.

Very early in my study of regeneration in *Cerianthus* it became evident that the rapidity of regeneration was more or less closely connected with the degree of distension of the piece. My observations along this line were made chiefly upon *C. solitarius*. In cases where closure of the ends and consequently distension by water was possible regeneration was much more rapid than in pieces where communication between the enteron and the exterior — other then the mouth and the aboral pore — existed. Observation of this apparent relation between water-pressure and regeneration led to experiment and it was soon possible to demonstrate that a very close relation between water-pressure in the enteron and regeneration existed. I am aware, of course, that Loeb ('91, '02) regards certain phases of this relation in *Cerianthus* as osmotic in nature. The results of his experiments and his interpretation will be discussed at another time: it need only be

said here that Loeb failed to understand the real conditions, otherwise he would scarcely have attempted to apply the osmotic hypothesis to this case.

The evidence bearing upon the relation between regeneration and internal water-pressure is varied in character. In the remaining portion of the present paper and in following papers the various lines of evidence will be discussed. First, however, it is necessary to call attention to certain features of the water-pressure and circulation in the enteron of normal animals. Except where statement to the contrary is made all observations and experiments were made upon *C. solitarius*.

Water-pressure and Circulation in the Enteron.

Under ordinary conditions both the body-wall of *Cerianthus* and the tentacles are subjected to a considerable degree of tension in consequence of internal water-pressure, the enteric cavity being distended with water. When contraction occurs this water issues through the aboral pore, at least in large part, though some passes out through the stomodæum. After loss of water from the enteron the body and tentacles are shorter and smaller, and, if the loss was great, are more or less completely collapsed. This condition continues until the enteron again begins to fill with water. As it fills, the body gradually resumes the original form exactly as does a rubber balloon when inflated with air. This distension of body and tentacles by water under pressure is an indispensable condition of the characteristic form of body and tentacles. The animal is incapable of extending to its full length or attaining its full diameter in any other way than through the medium of the internal water-pressure. Extension of the tentacles and the turgid condition often designated as erection is just as completely the result of the enteric water-pressure. Turgor of individual cells has absolutely nothing to do with the condition, as is evident to all who have examined with any care *Cerianthus* or other actinians. Loeb's belief ('91) that osmosis plays a part here is wholly without foundation, except so far as water may diffuse through the body-wall into the enteron.

We may regard *Cerianthus* as a sac filled with water under pressure. Under certain conditions the walls of the sac may de-

crease in size either locally or at all points, the result being in the first case increase of pressure and either stretching of other parts of the sac or loss of water through the pore or mouth, and in the second case always loss of water, commonly through the pore, and reduction in size of the whole body. While this sac has the power of contracting and forcing water out through certain openings, it has not the power of expanding actively and so drawing water in.

Since water under pressure is normally present in the enteron, and since after collapse due to contraction the pressure is soon reëstablished, means must exist by which water can be forced into the enteron against pressure. In my first paper (Child '03*a*) mention was made of the fact that regenerating pieces closed at both ends by their membranes of new tissue become distended with water in the course of a few days. It was suggested that in such cases water diffuses through the body-wall in consequence of the accumulation within the enteron of certain soluble products of metabolism. It is also possible that water may be secreted into the enteron together with these substances. To what degree the distension in normal animals is caused in this manner cannot be definitely ascertained, but it is certain that the rapid accumulation of water in the enteron of the normal animal after this has lost all or nearly all of its contents in consequence of violent contraction cannot be due to diffusion or secretion. In such cases the animal frequently regains its usual degree of distension within fifteen or twenty minutes, whereas distension by diffusion in regenerating pieces requires several days.

The few observations which have been made upon the siphonoglyphes in actinians indicate that the function of these structures is the production of currents through the stomodæum. Hickson ('83) found that in certain Alcyonaria, which possesses only one siphonoglyphe, the current was inward or downward along the siphonoglyphe and outward on the other portions of the stomodæal surface. It is probable further, according to Hickson, that the inward or downward current is continued along the free edges of the mesenteries for a greater or less distance below the siphonoglyphe, while on other mesenterial margins the cilia beat in the reverse direction, like those of the general stomodæal surface outside the siphonoglyphe.

According to this view there is an inward and an outward current in the stomodæum and for a greater or less distance aboral to it in the central region of the enteron between the margins of the mesenteries. According to my own observations conditions are very similar in *Cerianthus*. Only one siphonoglyphe is present (Fig. 1) and along this the current is directed inward, though whether the cilia may ever reverse this movement has not determined. The fact that small particles placed on the disc, if not ingested by muscular action, are gradually carried in a peripheral direction indicates that here the cilia beat so as to cause an outward current. The direction of the current on the lower parts of the œsophagus outside of the siphonoglyphe has not been determined, but is probably the same as upon the disc and upper portions. In Fig. 2 the opposing stomodæal currents are indicated by arrows, the inward current along the siphonoglyphe by the longer arrow on the left and the outer currents by two shorter arrows on the right.

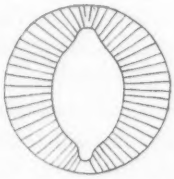

FIG. 1.

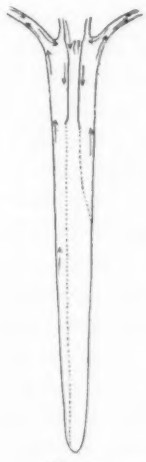

FIG. 2.

The natural conclusion is that the accumulation of water in the enteron is in some way the resultant of the stomodæal currents, but the manner in which this result is attained requires consideration. When the enteron is distended with water under pressure the walls of the œsophagus must be brought into contact since pressure is exerted upon them from all sides by the water in the enteron. The radiating grooves corresponding to the lines of attachment of the mesenteries, which are visible upon the disc of *Cerianthus*, extend the whole length of the stomodæum and probably it is along these that the chief outward currents pass. As the walls of the œsophagus are pressed more more closely together these grooves are more and more nearly obliterated. Probably when internal pressure is high the outward currents are very slight or absent. The siphonoglyphe, however, is a relatively powerful organ, which produces an in-

ward current. This groove is probably always open whether the body is distended or not. According to the laws of fluid pressure the force of the inward current need be only slight since the pressure it exerts is transferred to every unit of surface and in all directions in the enteron, *i. e.*, the principle by which enteric pressure is maintained is that of the hydraulic press; a slight pressure exerted over a very small surface is transferred to a large body of confined fluid and so multiplied many times.

If these suggestions are correct the passage of water in and out of the body and the process of distension and collapse are accomplished somewhat as follows: When the body is contracted it is probable that the œsophagus is more or less widely open; observation of living animals or sections of contracted specimens (Fig. 1) support this view. This condition of the œsophagus is probably brought about by contraction of the mesenteries which possess a slightly developed transverse musculature. In the contracted state then there is free passage of water in and out. When the muscles relax the œsophageal walls are again brought into more or less close contact, this result being, perhaps, brought about in part by the elasticity of the œsophageal walls or by muscular contraction, and in part by the circulatory currents in the intermesenterial chambers on all sides of the œsophagus (see Figs. 1 and 2). The approximation of the œsophageal walls decreases the outward currents, while the inward current continues, since the siphonoglyphe remains open. Thus, more water enters than passes out, and the result is of course gradual distension of the body. As the internal pressure increases the walls of the œsophagus are more and more closely appressed and thus the outward currents are decreased still further while the inward current continues undiminished. The increase in pressure and distension will continue until the motive power exerted by the cilia of the siphonoglyphe is just sufficient to balance the internal pressure and prevent an outward movement of water, and to replace any loss through outward currents, if such still continue, as perhaps they do to a slight extent. So long as the various conditions remain unchanged distension continues.

Let us now suppose that a sudden stimulus leads to contraction of the body-muscles. In the first stages of this contraction

the internal pressure must be greatly increased and probably the œsophageal walls are more closely appressed than before, since the muscles which separate them are weak. At this stage then little or no water escapes through the œsophagus. When the pressure reaches a certain point the aboral pore is forced open and rapid ejection of water occurs with considerable force. Thus the internal pressure is relieved, and now, as further contraction occurs, separation of the œsophageal walls takes place, and the remaining water passes out of the œsophagus, sometimes carrying with it mesenterial filaments in case of violent contraction. The point to which I desire to call especial attention is that when contraction begins the internal pressure closes the œsophagus all the more tightly, and it is not until this pressure is relieved by escape of water through the aboral pore that opening of the œsophagus can take place. Though few observations have been made on other species of actinians, I am inclined to believe that distension and collapse may be accomplished in much the same manner in other members of the group, the cinclides or other openings taking the place of the aboral pore. It is probable, however, that in many forms the muscles which separate the œsophageal walls are more powerful than in *Cerianthus* and so are able to bring about separation in spite of the internal pressure. It is perhaps needless to state that the ejection of mesenterial filaments through the cinclides or mouth is purely passive, the filaments being merely carried out with the water.

One other point may be mentioned in this connection: if the preceding observations and suggestions are correct it follows that the form of the œsophagus usually observed in transverse sections, viz., an oval with grooves at one or both ends (Fig. 1) is not what might be called the natural form, but a form resulting from contraction. Practically all fixed specimens of actinians are more or less contracted. It is extremely probable that when the animal is distended in the normal manner the œsophageal walls are always closely appressed except in the region of the siphonoglyphe. Dilation occurs of course in the taking of food, but it probably does not extend over the whole length of the œsophagus at one time and so does not cause any great loss of water. That the œsophagus is widely open in contracted

actinozoa is very evident from the frequent forcing out through it of mesenterial filaments; that it cannot be widely open during distension of the body by water is equally evident. Doubtless many differences in detail occur in different members of the group, but it is probable that the suggestions given here for *Cerianthus* will apply more or less closely to a large number of forms. The presence of two siphonoglyphes must condition certain modifications in these processes. The statement is made in several text-books that the siphonoglyphes serve to keep the water in circulation when the animal is contracted. According to the view given above, these organs serve rather to permit circulation when the body is distended.

In addition to the inward and outward currents in the stomodæal region the water in the intermesenterial chambers and in the tentacles connected with them is in constant circulation, impelled by the movement of cilia. I have not been able to determine the details of this circulation in *Cerianthus*, but have observed it in several transparent members of the group. In general it may be said that the current passes orally along the body-wall, peripherally along the aboral face of the tentacle, back again along its oral face, centrally beneath the disc, probably into and out of the labial tentacles, to the stomodæum, and aborally along the stomodæum. Whether cilia on the lateral surfaces of the mesenteries aid in forcing the water aborally I do not know. In the forms observed, at any rate, the aboral current continued from the aboral end of the stomodæum to the aboral end of the body. In all of the intermesenterial chambers are these circulatory currents. In *Cerianthus* itself they are difficult to demonstrate with certainty, but there is little doubt that the current in the oral direction along the body-wall exists, and this being present, we may confidently assert that the return current is also present. These currents in the intermesenterial chambers and tentacles may be designated for convenience as the circulatory currents in distinction from the inward and outward currents of the stomodæal region. They are indicated diagrammatically by arrows in Fig. 2.

How far the circulation of water in the central regions of the body is complicated by the complex arrangement of the mesen-

terial margins and mesenterial filaments cannot be determined. Moreover, these are merely matters of detail and do not affect the general outlines of the process. Since the position of the organs is subject to considerable variation the direction of local currents produced by their cilia must vary likewise.

This discussion of the internal circulation and pressure has been somewhat detailed, since I believe that the general internal pressure and perhaps also local pressure resulting from the impact of currents against the body-wall are important factors in form-regulation and without doubt also in development.

Internal Pressure, Growth and Form-regulation — A Preliminary Survey.

It is necessary before proceeding to the account of my experiments to indicate briefly how growth and form-regulation may be affected by the internal water-pressure. It would be difficult otherwise in many cases to show the bearing of the experiments without extended explanation.

It is conceivable that the presence of water in the enteron may affect the body-wall in two ways: first, by general pressure, the same in all parts of the body, which subjects the body-wall to tension; second, by local pressure resulting from the impact of definitely directed currents upon some portion of the body-wall which interrupts their course, thus subjecting that part of the body-wall to a localized tension in addition to the general tension.

The experiments to be described demonstrate clearly that regulation in *Cerianthus* is dependent in certain important respects upon the tension resulting from internal water-pressure. The tissues react to this tension by growth. In the absence of the tension the typical form of the animal does not appear. Up to this point the evidence afforded by the experiments can scarcely be doubted or refuted.

An essential feature in form-regulation in *Cerianthus*, as well as in other forms, is localized growth which is especially noticeable in the formation of new tentacles.

The problem of the cause of localized growth is one of the greatest importance in morphogenesis. According to one view the basis of morphological form is inherent in the organism,

either in the structure of the protoplasm or as a governing principle distinct from physical and chemical factors to which the latter are subordinated. On the other hand, it is possible, at least theoretically, to regard organic form as the resultant of the complex of physical and chemical conditions internal and external which affect the protoplasm. According to this view, organic form is not strictly speaking inherent in the living substance; but results indirectly from its activities and its environment.

The experiments to be described demonstrate, I believe, that in the absence of internal water-pressure the living substance of *Cerianthus* is absolutely incapable of producing the typical form of this animal. It is not merely that the parts are formed and remain collapsed in the absence of water-pressure; either they are not formed or their form is atypical. The appearance of the tentacles is delayed or is inhibited; the growth of the disc and the œsophagus does not occur when the internal pressure is reduced below a certain point. Thus it is possible in this case to demonstrate a general relation between internal water-pressure and growth.

The question as to whether any relation between localized growth and localized internal pressure exists must not be confused with the preceding question as to a general relation between the two phenomena. It is possible for instance to suppose that the region where new tentacles shall appear is determined in some unknown manner, but that the internal pressure is a factor in causing their growth after their position has been determined. On the other hand, it is possible to conceive that the position of these structures is determined by local pressure due to currents in the enteron (the "circulatory currents"). It cannot be claimed for my experiments thus far that they decide which of these two possibilities is correct. Certain of the data, however, appear to me to indicate that the local pressure due to currents may play a certain rôle in determining the position of the marginal tentacles. Concerning the labial tentacles there is as yet no definite evidence and this fact must constitute a weak point in the evidence, at least until further experiments can be performed.

Time need be taken here only for a brief consideration of the possibility of a direct relation between local internal pressure and

the determination of localized structures at certain points. In each intermesenterial chamber the circulatory current passing orally along the inner surface of the body-wall (Fig. 2) must strike against any part of the wall which is folded or rolled over in such a manner as to form an obstacle in its course. When a transverse cut in the body-wall of *Cerianthus* is made the cut edges roll inward in such a manner that the current passing orally in the chambers must strike the inner surface of the inrolled portion. In this condition that portion of each intermesenterial chamber just beneath the inrolled cut margin forms a blind sac into which water is continually being forced by the current. The cilia which in the normal animal provide for a return current have been in large part removed from this region. Local pressure upon the body-wall in this region must result. Now the marginal tentacles always make their appearance in exactly this region, a region which previously formed a part of the lateral body-wall, and which, since tentacle-regeneration is possible at any level except the extreme aboral region, cannot have possessed any special qualifications for tentacle formation. The question is, what causes tentacles to appear in this particular region of a piece, no matter what part of the body the original piece represents. Doubtless very few will regard the assumption of an "entelechy" (Driesch) or of "dominants" (Reinke) as an answer to this and similar questions, although it may possess the merit of many other unwarranted assumptions, viz., that of being an easy way out of difficulty. If we call in "heredity" to answer the question we still have no real answer, though it is evident that tentacles of characteristic form and structure would not appear if *Cerianthus* were not concerned. Are we not justified in seeking for definite, intelligible causes or conditions of one kind or another for phenomena of this nature? Much work of recent years has given an affirmative answer to this question. In many cases undoubtedly these causes or conditions are internal, *i. e.*, in the protoplasm, but it is by no means impossible or improbable that they are external in many other cases.

Certain of my experimental results seem to me not only to admit the possibility of local pressure as a determinative factor

in morphogenesis but to afford little basis for other interpretations. I desire to give the data in descriptive form, but shall endeavor to point out their bearing in connection with this hypothesis. It should be borne in mind, however, that while the existence of a general relation between internal water-pressure and growth is demonstrated, my data upon the other problem are insufficient in my own opinion to establish a conclusion without doubt. At present, though the evidence in regard to the marginal tentacles is very strong, the impossibility of giving any special evidence concerning the labial tentacles constitutes a serious defect. The regeneration of labial tentacles is certainly delayed or inhibited by reduced water-pressure, but I have not been able thus far to demonstrate that localized pressure upon the body-wall occurs in the region where they appear. This failure is due at least in part to the fact that my attention was concentrated chiefly on the marginal tentacles during my experiments. I hope that a future opportunity for renewed experimentation may render it possible to attain more definite conclusions on this point. Attention may be called to the possibility that the two sets of tentacles possessing different functions and appearing as they do at different times and under different conditions may perhaps be determined by very different factors. General similarity of form and structure is not necessarily indicative of similar conditions of origin. Even if it should be demonstrated that the marginal tentacles arise in response to the stimulus of localized pressure it would by no means necessarily follow that the labial tentacles are similarly produced.

The Closure and Distension of Pieces.

The closure by new tissue of the two ends of cylindrical pieces has been described in the first paper of this series (Child, '03*a*). The closure consists essentially in typical cases of the connection of all parts of the inrolled cut surface of the body-wall by a thin, delicate membrane of new tissue. The result of closure in this manner of both ends of the piece is the interruption of direct communication between the enteric cavity and the exterior. Nevertheless, water rapidly accummulates within the enteron, probably in consequence of diffusion or secretion, causing marked

distension of the piece. However the fluid may enter, the distension occurs in every case, and in three or four days after section (in summer) the pieces are subjected to a considerable degree of internal pressure.

The pressure of the water being exerted in all directions tends to stretch the body-wall. The thin delicate new tissue at the ends is the weakest part of the body-wall and therefore most effected by the stretching. After closure of the ends by new tissue and before distension has occurred, the new tissue is either invisible or scarcely visible from the exterior. The inrolled edges are closely approximated and all that can be seen of the new tissue in any case is the part filling in the spaces between folds and wrinkles of the cut surface. Moreover, if the inrolled margins of the body-wall be spread apart even with the greatest care at this stage the new tissue does not stretch to any great extent but is ruptured even by slight tension. Under these conditions the cut

FIG. 3.

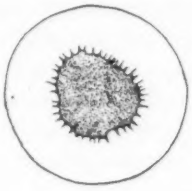

FIG. 4.

end presents somewhat the appearance of Fig. 3. The piece is collapsed, the margins are much folded and the only new tissue visible is the small area between the inrolled margins represented in the figure by the stippled portion.

These facts serve to introduce the chief point in the present consideration, viz., this: so long as there is no tension exerted upon this new tissue closing the ends it does not increase in surface-area, but mere differentiates into the typical structure of the body-wall. In other words the ends of the piece have no power in themselves to spread apart and thus initiate the formation of a new disc. What occurs in the typical course of regeneration is shown in Fig. 4. The inrolled margins are gradually spread apart while the thin membrane of new tissue uniting them — the stippled area in the figure — increases in area as they separate.

It is not difficult to show that this increase in area of the new tissue is due simply to the internal water-pressure. If the aboral end of the piece be prevented from closing or be punctured from time to time and thus the acclumulation of water in the enteron be prevented, the spreading of the oral end and the increase in area of the new tissue does not occur. The cut surfaces remain rolled inward and approximated as in Fig. 3, while the new tissue merely fills the spaces between them, but does not increase farther. A similar experiment affords the same result for the aboral end. In such cases the end retains the form acquired by inrolling of the margins (see Child, '03*a*, Figs. 3–5), differing from the stages figured only in that the crevices between the inrolled cut surfaces are closed by the new tissue.

Experiments of this kind were performed many times and always with the same result. Under conditions to be described later certain other regenerative processes may occur as usual in pieces which are kept open aborally, but in no case does the spreading apart of the cut surfaces at the oral end occur and in no case does the disc assume its typical form.

The increase in the area of the new tissue when under tension is not merely a stretching; as was noted above, attempts to stretch the tissue artifically always resulted in rupture. At the end of this extension of the new tissue its area is many times as great as at first and, what is more important, its thickness is as great as, or greater than before. Actual growth has without doubt occurred during the extension, indeed the conclusion is justified that the increase in area of the new tissue could not have occurred without growth; the attempts at artificial stretching leave little room for any other conclusion. If this conclusion is correct, then the growth of this new tissue is dependent on the tension to which it is subjected and not on any factor or condition existing in the tissue itself, except of course the power of growth. Unless the tissue is subjected to tension, growth ceases with the closure of the small spaces between the folds of the inrolled ends; when it is subjected to tension, within certain limits, it grows, *i. e.*, increases in quantity, number of cells, etc. Its increasing thickness and power of resistance to tension as differentiation occurs limit its growth, so that increase in area does not go beyond a certain point (Fig. 4).

In this case, as in the growth of new tissue between diverging cut surfaces described in the preceding paper (Child, '04), the localization and extent of growth is dependent, not on internal factors, but on simple mechanical conditions of tension.

The figures and the details of the description given refer to *C. solitarius*. The process of closure and distension in *C. membranaceus* differs in some details from this, though undoubtedly subject to similar conditions. It was shown in the preceding paper (Child, '04) that the new tissue in *C. membranaceus* is able to spread over larger areas and therefore to close larger openings than in *C. solitarius*, and moreover, that it is thicker and more resistant than in the latter species. Taking these facts into consideration we find that the process of closure and spreading of the ends is similar in both species. It is probable that the dependence of growth of the new tissue on tension would not have been so readily recognized in *C. membranaceus* if this form alone had been studied. The tissue after its formation is so resistant to tension that the distension of the piece is very commonly insufficient to bring about any considerable increase in the amount of new tissue after closure. Frequently, however, some growth after distension is recognizable, though it is usually relatively much less than in *C. solitarius*. This difference between these species indicates the importance of comparative study of related species in experimental work. Phenomena not readily interpreted in one species may be modified in another so that interpretation is without difficulty, and it is often possible, as in the present instance, to apply the interpretation obtained in the one case to the other, although its recognition in the first case would have been difficult or impossible.

Tentacle Regeneration in Relation to the Mesenteries.

Attention has already been called to the fact that tentacles do not regenerate in the absence of mesenteries (Child, '03*b*).

In regenerating ends representing levels near the oral end of the parent body the series of mesenteries is complete or nearly so; farther aborally, however, mesenteries are present over only a larger or smaller portion of the circumference, according to the level. In the pieces from these regions a certain number of mes-

enteries regenerate and the series thus becomes complete. Still nearer the aboral end only a few mesenteries are present on the directive side, and finally only a single pair. In most of the pieces from this region regeneration of the mesenteries does not occur, probably because of the decreased reactive capacity of the tissues in this region, as has been suggested (Child, '03*b*). In certain pieces from this region the regeneration of tentacles corresponding to the intermesenterial chambers was observed to begin but never proceeded far and no mesenteries were regenerated (see Fig. 3, Child, '03*b*). The fact that tentacles never appear in such cases where mesenteries are absent indicates that their regeneration is dependent in some manner upon the presence of the mesenteries. In pieces where regeneration of the mesenteries occurs, regeneration of the tentacles never precedes or coincides in time with the appearance of mesenteries, but always follows. Various observations of others and my own upon other species of actinozoa indicate that this rule holds good not only for regeneration but for the normal development and for addition of new tentacles in adults. The new mesentery appears first, then the tentacle.

The interpretation of this "correlation" is not difficult if we accept the point of view suggested above. According to this it is evident that the mesenteries serve to localize the currents proceeding orally along the body-wall, *i. e.*, the current of one intermesenterial chamber is separated by the bounding mesenteries from that in the adjacent chamber. If the mesenteries were not present the current would strike the oral margin in a continuous circle and if it produced any effect at all would cause the outgrowth of the whole margin.[1]

The outgrowth of the whole margin, *i. e.*, the spreading of the disc, occurs to a certain extent in every case of regeneration and

[1] It is conceivable that in such a case the surface tension of the outgrowing margins might operate in such manner as to cause it to break up into a number of radiating masses of certain size. It is not impossible that the tentacles of certain cœlenterates are formed in some such manner whether the stimulus to growth be water-pressure or some other. This process might be compared to the breaking up of the margins of a drop of fluid into radiating cylindrical masses, which occurs when it is allowed to drop with force upon a smooth hard surface and "splashes." In this case we have a continuous cause with discontinuous effect. The close relation between the number of tentacles and the size, *i. e.*, the circumference, in such forms as *Hydra*, indicates the possibility of an explanation of this kind.

is probably due to the combined effect of the currents about the whole circumference, but the localized effect is much greater, giving rise to the long marginal tentacles. In its earlier stages the intermesenterial chamber formed between two regenerating mesenteries is simply a small blind pocket into which the water passing orally along the wall of the enteron is continually forced. In the normal animal there is a current passing aborally along the stomodæum (see Fig. 2), thus carrying the water out of the pocket, but in the earlier stages of regeneration the stomodæum and disc are absent; *i. e.*, no cilia, or few, are present to produce a current in the aboral direction. On the other hand the current passing orally is not necessarily diminished by section. The consequence is that water is continually forced into the oral end of the intermesenterial chamber and strikes the body-wall with a certain pressure, but no means for its removal exists except as the incoming water displaces it.

It is clear without further discussion how the localization of the regenerating tentacles and their dependence upon the presence of mesenteries can be accounted for as a reaction to the tension produced by internal water-pressure.

Local Inhibition of Tentacle Regeneration.

The shape of the collapsed pieces after section and before closure and distension is various. Frequently some part of the oral end — as well as other regions — becomes involved in some fold or wrinkle in consequence of collapse. The new tissue binds the cut surfaces together however they may happen to lie, but if distension occurs within a few days the folds are soon obliterated because the growth of the new tissue corresponds to the tension. If, however, distension be prevented by keeping open the aboral end while the oral end is permitted to close, the new tissue uniting the cut surfaces thickens and becomes more resistant to tension in the course of a few days.

After two weeks or more, even if the piece is allowed to close aborally and become distended, the fold may persist for a long time, since union of the oral end has occurred in the folded condition and the new tissue is now so resistant that only very gradual change occurs. It is easy to see that when such a piece be-

comes distended with water after closure it may be impossible or difficult for the water to gain entrance into the intermesenterial chambers of the folded part and so this may fail to be distended; if it is not distended it will be compressed to a greater or less extent by the adjacent distended regions. In this manner it is possible to produce experimentally cases in which only a part of the circumference becomes distended with water after closure. In all such cases it is found that the tentacles appear only on the distended portions. If the infolded or compressed portions become distended later, tentacles appear.

Provided the aboral end is kept open long enough, tentacles may appear in those regions where the mesenterial chambers are sufficiently open to permit the entrance and circulation of water. Of course the formation of tentacles is much slower in this case than when the piece is permitted to distend, and they never attain very great length. Since the regeneration of the tentacles is very slow and does not proceed far, this method is less satisfactory than the first.

By both of these methods it is possible to bring about local inhibition of tentacle-regeneration. In some cases the folded or compressed region includes only one or two mesenterial chambers, and here only one or two tentacles are inhibited or delayed. In pieces with slightly irregular oral margins where closure is irregular there is often great irregularity in the tentacles, some appearing early, others late, but in every case it can be determined that the tentacles appear first on those parts where distension and the circulation of water is least hindered, and *vice versa*.

There is very rarely any difficulty in distinguishing the distended portions of the body from those that are collapsed or compressed; the former appear somewhat translucent and the surface is smooth; the latter are opaque and usually more or less wrinkled. Moreover there is a distinct difference in color between distended and collapsed portions, the former being always lighter in color, since distension stretches the body-wall and the stripes (in *C. solitarius*) are farther apart or the pigment granules (in *C. membranaceus*) less densely distributed. Thus distended parts can usually be distinguished at a glance from

those which are collapsed. It is possible to observe on the living specimens that the tentacle regeneration is more rapid in distended than in collapsed portions. Though it may not always be possible to determine exactly the causes that have operated in bringing about a particular case of local collapse or compression its presence can be recognized without difficulty, even before tentacle regeneration has begun.

A few examples selected from the numerous cases of this kind observed will serve to illustrate the subject. Fig. 5 represents a case in which one side of the oral region of a piece became folded inward during collapse and so failed to become distended when closure was allowed to occur. It will be observed that the new tissue closing the oral end does not form a rounded area but simply fills the crevices between the inrolled margins. The failure of the new tissue to distend is due to the fact that the aboral end was kept open until the new tissue had become thick

FIG. 5.

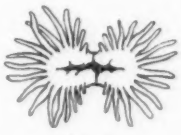

FIG. 6.

enough to resist the tension and to grow very slowly. It will also be observed that with approach to the infolded region the marginal tentacles decrease in size and finally cease. The region without tentacles represents a much greater portion of the circumference than is apparent in its contracted condition. The figure is simply a view of the oral end. A short distance from the end the fold disappears and the body is cylindrical in form. The fold was gradually obliterated in this piece and the missing tentacles finally appeared.

In Fig. 6 a similar case is shown, except that here two folds are present on opposite sides of the body. In the region of each of these folds the tentacles diminish in size and disappear as in the case of Fig. 5.

In these cases it is of course impossible to determine just why the water has failed to enter the infolded portions, but it is prob-

able that the mesenteries of these parts are so closely pressed together that the mesenterial chambers are almost obliterated and their communication with the general enteric cavity almost or quite shut off. After the other parts have once become distended these collapsed parts are compressed. Only as water gradually finds its way into them, either by diffusion or through small openings, will they become distended so as to permit the typical circulation.

A case obtained in a similar manner from a piece of *C. membranaceus* is shown in Fig. 7 (natural size). It could be seen without difficulty that the three regions bearing the long tentacles were distended while the intermediate regions were not or were only slightly. In the course of a few weeks the distension of all parts gradually become uniform and the delayed tentacles finally attained the same size as the others, though only after the others had ceased to elongate. Of course at a somewhat earlier stage than that figured not even minute tentacle-buds were present on the infolded regions though the tentacles on the distended regions were already well developed. In this case as in the others it is probable that in the infolded regions the mesenteries are so closely pressed together that little water enters the chambers.

FIG. 7.

These experiments have a certain bearing upon the question of localized pressure as a factor in determining the position of the marginal tentacles. It is evident that in the distended portions the circulatory currents must possess greater force and volume than in the collapsed portions, where they may indeed be absent or insufficient to act as stimuli. If the appearance of the marginal tentacles is due to the local pressure resulting from these currents it is easy to see why the tentacles appear earlier on the distended portion. In general internal pressure we can find no factor which can determine the position of these organs, and if they are determined by "protoplasmic" factors it is difficult to understand why they should appear earlier on the distended portions than on the others.

SUMMARY.

1. Except when the animal is contracted or collapsed the body-wall of *Cerianthus* is subjected to a certain degree of ten-

sion in consequence of the fact that the water in the enteron is under pressure.

2. The inward current along the siphonoglyphe is probably the means by which the internal pressure is established and maintained.

3. When the body is distended the œsophagus, with the exception of the siphonoglyphe and perhaps some grooves and crevices, must be closed.

4. When contraction occurs the water first issues from the aboral pore (in other actinians from the cinclides, etc.); then when the pressure is sufficiently reduced to permit it, the œsophageal walls are separated by muscular action and the remaining water issues from the mouth, often accompanied by mesenterial filaments. Thus the œsophagus is widely open only during extreme contraction.

5. The cilia on the entodermal surface of the body-wall produce a current flowing orally in each mesenterial chamber. The water passes from each chamber along the aboral face of the marginal tentacle, back on its oral face beneath the disc toward the stomodæum, probably into and out of the labial tentacles and aborally along the stomodæum. In all probability cilia along the sides or margins of the mesenteries force it further aborally.

6. The internal water-pressure plays a large part in form-regulation in *Cerianthus*. The general pressure affects the rapidity of growth wherever it may be taking place and it is possible that the local pressure exerted on the body-wall by the currents passing orally in each mesenterial chamber is the formative stimulus for the marginal tentacles.

7. Regeneration of tentacles is impossible unless mesenteries are present. The reason suggested for this is that in the absence of mesenteries there is no localization of the currents corresponding to the intermesenterial chambers, and, moreover, the water being unconfined between mesenteries, exerts less pressure on the inrolled oral end than if mesenteries were present.

8. Local retardation or inhibition of tentacle-regeneration can be brought about by preventing distension of a part or parts of the oral region.

HULL ZOÖLOGICAL LABORATORY,
UNIVERSITY OF CHICAGO, September, 1903

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NOTES ON REGENERATION IN TUBULARIA CROCEA.

HELEN DEAN KING.

The following experiments on *Tubularia* (*Parypha*) *crocea* were made during the summer of 1903, at Woods Holl, Mass., while I was occupying a research room of the Carnegie Institution in the Marine Biological Laboratory. The work was done under the direction of Prof. T. H. Morgan to whom I am indebted for many helpful suggestions.

I. The Effect of the Earlier Closing of One End of a Long Piece of the Stem of Tubularia.

In experimenting on the European hydroid *Tubularia mesembryanthemum*, Morgan (10) allowed the ends of long pieces of the stem to close and then, after an interval of from one to eight hours, he cut the pieces transversely through the middle region so that two new cut surfaces were exposed (Fig. 1, *B*, *C*). As a result, the aboral development of the proximal piece *CD*, was hastened. In many cases a polyp appeared on the aboral surface, *D*, as soon as did a polyp on the oral end, *C*, and in a few pieces a hydranth developed at *D* as early as did the hydranth on the distal end of the anterior piece, *AB*. This result is explained by Morgan as follows: "When a piece is cut in two in the middle one, two, three or more hours after its ends have closed, the influence of the oral end is temporarily removed, and the aboral end, which now has a start on the new oral end, may gain the ascendency and be the first to produce a polyp. Often, however, the polarity of the piece is sufficiently strong to give the precedence to the influences acting on the oral end. When the two influences are equally balanced, two hydranths may simultaneously develop."

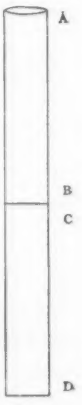

Fig. 1.

In repeating these experiments on the American hydroid,

Tubularia crocea, the hydranths already present at the anterior ends of the stems were removed by a transverse cut about 2 mm. behind the proximal circle of tentacles, and then pieces of stem varying in length from 30–40 mm. were cut off and the ends allowed to close. After an interval of from two to eight hours the stems were cut through the middle as in Fig. 1, *B*, *C*, thus producing a freshly cut surface (Fig. 1, *B*) at the aboral end of a distal piece, and also one at the oral end (Fig. 1, *C*) of a proximal piece. The results of this series of experiments are given in Table I. to IV. The first column gives the total number of individual stems operated upon; the second column shows the time that elapsed between the removal of the hydranth and the cutting of the stem through the middle; and in the following columns the results two, three, and four days after the operation are indicated. *Hy.* signifies the regeneration of a complete hydranth; *t. a.* indicates the formation of tentacle anlagen only; while *O* is used to indicate that no regeneration had taken place when the observations were made. The letters *A*, *B*, *C* and *D* refer to surfaces thus marked in Fig. 1; and the numbers in parentheses show the number of cases in which similar results were obtained.

TABLE I.

Number of Individuals.	Interval Between Cuttings.	Result in Two Days.	Result in Three Days.	Result in Four Days.
6	2 hours.	*A* ...*hy.* (6) *B* ... *O* (6)	*A* .....same. *B*	*A* .....same. *B*
		C....*t. a.* (3), *O* (3) *D*... *O* (6)	*C*....*hy.* (4), *t. a.* (2) *D*... *t. a.* (2), *O* (4)	*C*.....*hy.* (6) *D*...*hy.* (2), *t. a.* (1), *O* (3)

Owing, probably, to differences in the temperature of the water in which they live, regeneration in *Tubularia crocea* is much slower than in *Tubularia mesembryanthemum*. In the former species a new hydranth rarely develops until two days after the removal of the old hydranth, while in the latter species a new hydranth frequently regenerates in the course of twenty-four hours. In all of the experiments in this series, as shown in the above table, a polyp formed on the oral end, *A*, of the anterior

piece, *AB*, before one developed on the oral end, *C*, of the proximal piece, *CD*. This result might, of course, be expected as the oral end, *A*, closed two hours before the end, *C*. In no case did a polyp develop at the aboral end, *D*, of the proximal piece as soon as one formed at the oral end, *C*. A start of only two hours, however, is sufficient, in most cases, to cause the formation of a hydranth at *D* before one develops at the aboral end, *B*, of the distal piece, *AB*.

The results obtained when the intervals between the cuttings were four, six and eight hours are given in Tables II. to IV.

TABLE II.

Number of Individuals.	Interval between Cuttings	Result in Two Days	Result in Three Days.	Result in Four Days.
10	4 hours.	A ... hy. (6), O (4); B ... O (10); C.... t.a. (1), O (9); D ... O (10)	A ... hy. (6), t.a. (4); B ... O (10); C.... hy. (2), t.a. (5), O (3); D ... t.a. (1), O (9)	A ... hy. (10); B ... t.a. (2), O (8); C.... hy. (7), t.a. (3); D ... hy. (1), O (9)

TABLE III.

Number of Individuals.	Interval between Cuttings.	Result in Two Days.	Result in Three Days.	Result in Four Days.
8	6 hours.	A ... hy. (3), t.a. (3), O (2); B ... O (8); C.... hy. (1), O (7); D ... O (8)	A ... hy. (6), t.a. (2); B ... O (8); C.... hy. (5), t.a. (3); D ... t.a. (4), O (4)	A ... hy. (8); B ... O (8); C.... hy. (8); D ... hy. (4), O (4)

TABLE IV.

Number of Individuals.	Interval Between Cuttings.	Result in Two Days.	Result in Three Days.	Result in Four Days.
12	8 hours.	A ... hy. (6), t. a. (4), O (3); B ... O (12); C.... O (12); D ... O (12)	A ...hy. (12); B ...O (12); C.... hy. (10), t. a. (2); D ... hy. (2), t. a. (3), O (7)	A ...hy. (12); B ...O (12); C....hy (12); D ... hy. (5), O (7)

There is a great similarity in the results of these experiments. In all cases a hydranth formed on the oral end, *A*, of the anterior piece before one developed at any other cut surface, and the rate of development of a polyp from the aboral surface, *D*, was more rapid than that from the aboral surface, *B*, even in those cases in which *D* had only two hours start over *B*. In no case, however, did a polyp form at *D* before one developed at *C*, even in the experiments in which *D* closed eight hours before *C*. As was the case in the experiments made by Morgan, an interval of eight hours between the two cuttings has, apparently, no more effect on the regeneration than has an interval of only two hours. The formation of a polyp at the oral end, *C*, of the proximal piece, *CD*, does not prevent the early development of a polyp at the aboral end of the same piece, and in some cases there is only a few hours interval between the formation of the two hydranths. The earlier development of a hydranth at *A*, however, seems to check the formation of a hydranth at the aboral end, *B*, of the distal piece for some time, as in no case did a hydranth develop at *B* until five days after the experiment began. This difference in the rate of development at *D* and at *B* cannot be due to a difference in the lengths of the pieces, because, in making the experiments, the stems in all cases were cut as nearly as possible through the middle and any difference in the lengths of the anterior and of the proximal pieces would be too slight to have any appreciable influence on the result. The earlier closing of the aboral end, *D*, of the proximal piece, *CD*, evidently counterbalances to some extent the influence of the oral end, as suggested by Morgan. As a result, the development of a polyp at *D* is hastened somewhat, although in no case is a hydranth formed here before or as soon as one develops at the oral end of the piece.

The effect of the earlier closing of the aboral end of long pieces of the stem, in both *Tubularia mesembryanthemum* and in *Tubularia crocea*, is to hasten the development of the aboral surface. The influences that bring about this result are apparently not as strong in the latter species as in *Tubularia mesembryanthemum* where the aboral development may be hastened so much that polyps develop simultaneously at both ends of the piece.

This seeming difference between the two species may possibly be due to the fact that *Tubularia crocea*, which lives in cold water, regenerates very slowly and, therefore, comparatively slight differences in the rate of regeneration at the oral and aboral ends of the stem can be readily noted. *Tubularia mesembryanthemum*, on the other hand, lives in much warmer water and its regeneration takes place so quickly that it is difficult to detect slight differences in the rate of development of the polyps at the cut oral and aboral surfaces.

In a variation of the above experiment, a piece of silk thread was tied tightly around the stem about 2 mm. below the hydranth, and another piece was tied about 30–40 mm. below the first. Both ends of a long piece of stem were, therefore, closed at practically the same time in such a way that no regeneration was possible from either end of the piece. After the ends had been tied, the stem was cut transversely through the middle as in Fig. 1, *B*, *C*, in order to ascertain whether subsequent regeneration from the cut surfaces, *B*, and *C*, would be hastened in comparison with the rate of regeneration from similar surfaces of pieces of stem of the same length, cut at the same time, but not closed artificially at one end. The control pieces of stem were kept in the same dishes with those used in the experiment, and both sets, therefore, were under the same external conditions.

Eight long pieces of stem were used in this experiment. Two days after the operation, tentacle anlagen had appeared at the cut ends of all of the sixteen pieces, but they were not as well developed on the aboral end, *B*, of the anterior piece as they were on the oral surface, *C*, of the posterior piece. At this time there was no indication of any regeneration at the aboral surface of the anterior piece in the control set of stems, although in some cases complete hydranths, in other tentacle anlagen, were present on the oral end of the proximal pieces. On the third day after the operation, polyps were found on the oral end, *C*, of all of the proximal pieces, both in the control and in the tied stems. The development from the aboral surface, *B*, of the anterior pieces, however, did not keep pace with that at the oral end, *C*, of the proximal pieces, as at this time only two of the pieces of stem tied at one end had produced hydranths at the aboral sur-

face, *B*, the rest had, as yet, developed only tentacle anlagen; in the control stems, no development from the aboral surface, *B*, had taken place in any case.

It is seen from the above experiments, that the development of a hydranth at the oral end of a piece of the stem of *Tubularia crocea* is not hastened by artificially closing the aboral end. Tying the oral end of a distal piece of the stem, however, hastens the development of the aboral end of the piece as compared with the development that takes place from the aboral surface of a piece of stem of similar length that is not closed at the oral end, as Driesch has shown. This result also agrees with that obtained by Loeb (7) in experiments in which he stuck the oral end of pieces of the stem of *Tubularia mesembryanthemum* in fine sand, leaving the other end freely surrounded by water. He found that "Durch Hemmung der Polypenbildung am oralen Ende kann man also die Polypenbildung am aboralen Ende beschleunigen."

In a third set of ten experiments, hydranth bearing stems about 30 mm. in length were removed from the colony and kept until a polyp formed on the cut aboral end. The time required for the development of these aboral polyps varied from three to five days in different cases. After all of the pieces had developed hydranths at the aboral end, each stem was cut transversely through the middle as in Fig. 2, *B*, *C*. The object of these experiments was to ascertain whether the presence of a hydranth at the aboral end, *D*, of the proximal piece, *CD*, would alter the polarity of the piece and thus prevent or retard the development of a hydranth at the oral end, *C*. The stems were cut through the middle region on June 19. Not until June 22 were there any indications of a development of a hydranth at the oral surface, *C*, and then only faint traces of tentacle anlagen were found in three stems. At this time, no development had taken place from the aboral surface, *B*, of any of the anterior pieces, *AB*. For control experiments, pieces of stem about 30 mm. in length were cut through the middle as in Fig. 1, *BC*, at the same time that the transverse cuts were made across the stems bearing a hydranth at each end, and on June 22, well developed hydranths were present at the oral end of all of the proximal pieces. On

June 23, three of the ten proximal pieces of stem bearing aboral hydranths had also developed hydranths at the oral end; while the oral end of two other pieces of stem showed well developed tentacle anlagen which developed into hydranths on the following day. No further changes took place in any of the pieces although they were kept for some ten days longer.

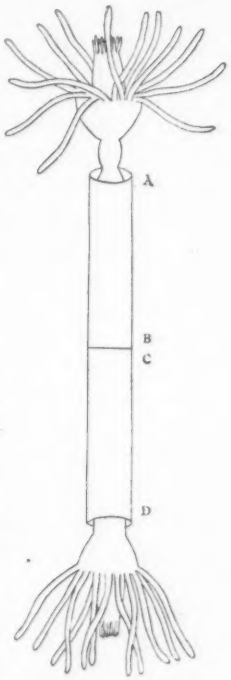

FIG. 2.

It is seen from the above experiments, that the presence of a hydranth at the aboral end of a piece of the stem of *Tubularia* delays, but does not prevent, the development of a hydranth at the oral end of the piece. This result cannot be due simply to the fact that the proximal end of the piece was closed by the presence of the aboral polyp, because, in the previous set of experiments, it was shown that closing the aboral end of a piece of stem by tying does not delay the development of a polyp at the oral end. It seems probable that the polarity of the piece was changed, for a time at least, by the presence of a hydranth at its aboral end and, therefore, the influences for hydranth formation at the freshly cut oral surface were not strong enough to bring about the development of a polyp for some days.

II. EXPERIMENTS ON BRANCHING STEMS.

The following series of experiments were made in order to ascertain whether the development of a hydranth on the oral end of a stem will influence the rate of development of a hydranth on the distal end of a long or of a short piece of a branch, and also to determine what conditions are necessary in order that the formation of a hydranth at the one place will prevent the formation of a hydranth at the other.

Series 1. — On June 24, twenty experiments were made in which a branch was cut off about 1 mm. from its origin in the stem, and then the anterior end of each stem was removed by a transverse cut leaving a piece from 10–20 mm. above the place of union with the branch (Fig. 3). In one case, a hydranth developed on the cut end of the branch two days after the operation, and at the same time a polyp also formed on the oral end of the main stem which in this instance was 20 mm. in length above the origin of the branch. In all other individuals at this time tentacle anlagen had formed at the oral end of the stem, but there was no indication of the development of a hydranth at the cut end of any of the branches. On June 27 hydranths were found at the oral end of all of the stems and also on the distal end of four branches; all the remaining branches had well developed tentacle anlagen excepting one which showed no signs of regeneration during the course of the week that the hydroids were kept. In this set of experiments, therefore, with the exception of the one case noted, regeneration of a hydranth took place at the distal end of the long stem before a polyp formed at the oral end of the short branch.

FIG. 3.

The results of this set of experiments might possibly be considered to be due to the fact that the longer piece exerted some kind of an influence over the shorter piece that would tend to alter the polarity of the shorter piece and thus retard development from its cut oral surface. That a larger piece of a hydrozoa can influence the polarity of a smaller piece is shown unquestionable in grafting experiments that I made on *Hydra viridis* (King, 6) in which the larger component of the graft either absorbed the smaller component or formed a permanent union with it. In the latter case, the polarity of the smaller piece was completely reversed, if necessary, in order that a structure might regenerate on its cut surface that would produce a normal polyp. Another factor that might, possibly, cause a delay in the development of a hydranth from the cut surface of the shorter piece is the length of the piece. Morgan has shown that in

branching stems a short piece of a branch or of a stem regenerates as does an isolated short piece, *i. e.*, the region of the tentacle anlagen is reduced and the rate of development of a hydranth is much slower than that of a hydranth from the cut end of a long piece of stem. Both of these factors may help to bring about the delay in the development of a hydranth from the oral end of the shorter piece in all of these experiments with branching stems in which there is a marked difference in the length of the stem and of the branch.

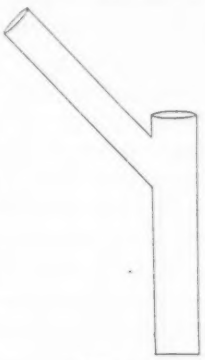

FIG. 4.

Series 2. — Seventeen branching stems from different colonies were cut so that the anterior portion of the stem above the place of union with the branch was only about 1 mm. in length, while the length of the branch varied in different cases from 8–25 mm. (Fig. 4). Two days after the operation, hydranths had developed at the cut ends of thirteen branches, and well developed tentacle anlagen were found at the oral ends of the other four branches. No hydranths were found at this time at the oral end of any of the stems, and tentacle anlagen were only faintly defined in some few cases. On the next day, hydranths had developed at the distal end of all of the branches, but only five stems bore hydranths at the oral end. In this set of experiments the development of a hydranth took place more rapidly from the cut end of the long branch than from the oral end of the main stem.

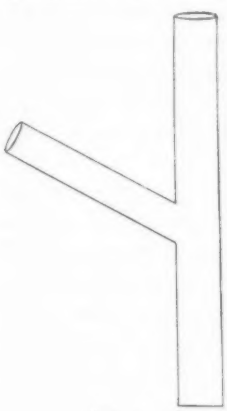

FIG. 5.

Series 3. — Twelve experiments were made in which the anterior end of the stem and the distal end of the branch were cut off so that the length of the branch and of the stem above the place of union was practically the same, varying in different cases

from 8–20 mm. (Fig. 5). Two days after the operation, there were well developed hydranths on the ends of three branches and only tentacle anlagen on the oral ends of the corresponding stems. In two cases hydranths had developed on the end of the branch and also on the cut surface of the stem; while in the other cases only tentacle analgen were found, and they were equally well-developed on the branch and on the oral end of the stem. During the following two days, hydranths formed on all of the cut ends, sometimes the hydranth developed on the end of the stem before it did on the branch, and sometimes the hydranth appeared first on the branch. As a general result of this series of experiments it can be stated that hydranths develop at about the same rate when both the branch and the anterior portion of the stem are approximately the same length.

Series 4. — In the previous set of experiments both the branch and the anterior portion of the stem were of considerable length and both developed at about the same rate. In order to see if similar results would be obtained if the pieces were very short, fifteen experiments were made in which the branch and the stem were cut off about 1 mm. above their point of union (Fig. 6). When the hydroids were examined three days after the operation, hydranths were found on the oral end of the stem and not on the cut end of the branch in five cases; while in four hydroids, polyps had developed on the branch and not on the oral end of the stem; in the remaining six cases, hydranths were present at the distal end of both branch and stem.

FIG. 6.

In those cases in which one or the other cut surface failed to develop a hydranth, the cœnosarc appeared to be entirely with drawn from this part. When these stems were examined under the microscope, the streaming of granules in the interior cavity was visible only in the proximal part of the main stem and in the part of the stem or branch that had regenerated. In the cases in which hydranths formed at both cut surfaces, the streaming of granules was found in all parts of the stem and also in the branch.

In this set of experiments, regeneration seemed to take place

with equal rapidity from the cut oral surface of the branch and of the stem, as was the case in the experiments described under series 3. If the pieces above the place of union of the branch and stem are of approximately the same length, no matter how long or how short they may be, the influences for hydranth formation appear to be alike in both, and one piece has, seemingly, no effect on the other. Where the cœnosarc is withdrawn entirely from one part of the hydroid, as was noted in some few cases in the last set of experiments, no regeneration of the piece is possible.

In experimenting on *Tubularia crocea*, Morgan (9) found that if he cut off both the main stem and the branch a little above the place of union, the results varied considerably in different cases. In some instances he obtained the regeneration of a hydranth on the branch and not on the oral end of the stem; in other cases a polyp formed only at the oral end of the main stem; and in still other individuals regeneration took place from the cut surfaces of both branch and stem. It seems probable that the lack of uniformity in these results can be attributed to a difference in the relative lengths of the branch and of anterior portion of the stem above the point of insertion of the branch. It is, of course, impossible to cut the branch and stem at absolutely equal distances from the place of their union, and in those cases in which regeneration from one cut surface took place before it did from the other, there may have been just enough difference in the lengths of the pieces to bring about the earlier regeneration of a hydranth on the cut oral surface of the longer piece.

FIG. 7.

Series 5. — In twenty-eight cases the stem was cut off transversely just above the origin of the branch as shown in Fig. 7. The oral end of the branch was then removed leaving a piece, from 3 to 5 mm. in length, still attached to the stem. The object of these experiments was to see whether the regeneration of a hydranth at the oral end of the stem could be entirely prevented by this means. Two days after the operation, hydranths had developed at the cut end of the branch in nine of the hy-

droids and well-developed tentacle anlagen were present on the other branches; there was no indication of a regeneration at the oral end of any of the stems. The next day all of the branches bore hydranths, and in but one case had any regeneration taken place at the oral end of the stem. In this instance, the stem extended about 0. 5 mm. above the place of insertion of the branch and a considerable amount of red pigment had collected at its extreme oral end. In the course of forty-eight hours more a polyp formed on the oral end of this stem but no regeneration took place at the oral end of any of the other stems, although they were kept for over a week.

Series 6.— Sixteen experiments were made in which the branches were cut off very close to their origin on the stem. The oral end of the stem was then removed leaving a piece about 5 mm. in length above the origin of the branch, in order to see whether the formation of a hydranth at the oral end of the stem would prevent or merely delay the formation of a polyp at the place where the branch was removed. In all cases the wound in the side of the stem healed over very quickly and, although the hydroids were kept alive for a number of days, no regeneration of any kind took place at the point of injury.

Series 7. — In ten cases the entire branch was removed from the stem, but the old hydranth at the distal end of the stem was not cut off. The result was the same as in the previous set of experiments, as the cut surface was very soon covered over and no subsequent regeneration took place from it.

Series 8. — In sixteen cases where long pieces of stem bore from two to four branches, the anterior end of the stem and the apical end of each branch were removed by transverse cuts leaving the lengths of the branches approximately the same as that of the stem above the origin of the most anterior branch. The experiments were made to see if there is any difference in the relative rate of regeneration of the anterior branches and of the proximal ones. There was no uniformity whatever in the results of this set of experiments. In some cases a hydranth regenerated on a posterior branch before it did on the oral end of the main stem; and in other cases all of the branches produced hydranths at the same time that one developed at the oral end of the stem.

III. The Regeneration of Short Pieces of the Stem of Tubularia.

It was first noted by Bickford (1), and later confirmed by Driesch (2) and by Morgan, that small pieces of the stem of *Tubularia* about 1 mm. in length are capable of regenerating. In a recent paper, Hargitt (5) states that he was unable to obtain any regeneration from pieces of the stem of *Tubularia crocea* and of *Tubularia tenella* that were as much as 3–4 mm. in length. This result was probably due to the poor condition of the stems when the experiments were made. Small pieces of the stem of some other hydroids, do not appear to possess as great a power of regeneration as *Tubularia*, for Gast and Godlewski (4) have found that pieces of the stem of *Pennaria cavolinii* about 1 mm. in length never produce hydranths and pieces 2 mm. in length regenerate hydranths but rarely. Bickford's experiments on small pieces of the stem of *Tubularia tenella* show that, in this species, regenerative processes are not restricted to any special region of the stem, and also that such short pieces tend to form one complete hydranth rather than to produce double abnormal structures.

In experimenting on *Tubularia mesembryanthemum*, Driesch (2) found that of 82 short pieces of stem, 5 formed a single proboscis, 26 formed a double proboscis, and the remaining 51 pieces produced hydranths. These results agree with those of the earlier experiments of Bickford. In a later paper, Driesch (3) states that at the oral end of the stem one seldom gets a whole hydranth, but usually a single or a double proboscis; from the middle zone hydranths usually develop; while from the aboral end of the stem, these structures are rarely produced. This difference in the kind of regeneration from the various parts of the stem Driesch attributes to the situation of the small piece in the original individual and to the different distribution of the hydranth-forming pigment in the cœnosarc of the different parts. Since Morgan and also Stevens (11–12) have proven the fallacy of the hypothesis of "red formative stuff" in *Tubularia*, this portion of Driesch's explanation is, of course, no longer tenable.

Morgan (8–10) has made an extended series of experiments with small pieces of the stem of both *Tubularia mesembryanthemum*

and of *Tubularia crocea*. He finds, as did Driesch, that pieces about 1 mm. in length from the region immediately behind the old hydranth usually die, even when longer than pieces from a more proximal region that regenerate. When this distal region does regenerate, it produces a greater number of single proboscides than of other forms, a result that might be expected as this part of the stem ordinarily goes into the proboscis of the new hydranth when a long piece of stem is regenerating.

In another set of experiments, Morgan cut pieces of the stem of *Tubularia mesembryanthemum* into a series of small pieces about 1 mm. in length in order to observe the behavior of consecutive pieces from one stem and to compare the results with those obtained from similar pieces cut from other stems. His tables do not show any very definite results although there seems to be a certain similarity in the behavior of pieces of the same stem, and the incomplete structures are found most frequently at the distal end of the stem.

At the suggestion of Professor Morgan, I repeated his experiments, using *Tubularia crocea*, in order to furnish more data from which definite conclusions could be drawn. In making the experiments the old hydranths were removed and the distal part of the stem was cut into consecutive pieces about 1 mm. in length. The pieces were than laid in rows on the bottom of flat dishes filled with fresh sea water. For the sake of brevity the following abbreviations are used in the tables given: hy. = complete hydranth without any stalk; hy. + stalk = hydranth with a short stalk that has been formed by a withdrawal of the cœnosarc from the perisarc; hy. + stem = hydranth with a stem attached to the perisarc; pb. = single proboscis; d. pb = double proboscis; reprod. = reproductive organs. The results tabulated are from observations made three to four days after the operation.

TABLE V.

Number of Piece.	Kind of Structure Regenerated.	Number of Piece.	Kind of Structure Regenerated.
1	pb. with no tentacles.	6	pb.
2	d. pb.	7	d. pb.
3	pb.	8	hy. + stem.
4	d. pb. + reprod.	9	d. pb.
5	pb.	10	d. pb.

TABLE VI.

Number of Piece.	Kind of Structure Regenerated.	Number of Piece.	Kind of Structure Regenerated.
1	pb.	6	dead.
2	d. pb.	7	pb.
3	d. pb.	8	pb.
4	dead.	9	dead.
5	d. pb.	10	dead.

TABLE VII.

Number of Piece.	Kind of Structure Regenerated.	Number of Piece.	Kind of Structure Regenerated.
1	d. pb.	6	d. pb.
2	pb.	7	d. pb. + reprod.
3	pb.	8	pb.
4	pb.	9	hy. + stem.
5	hy.	10	pb.

TABLE VIII.

Number of Piece.	Kind of Structure Regenerated.	Number of Piece.	Kind of Structure Regenerated.
1	dead.	6	pb.
2	d. pb.	7	pb.
3	d. pb.	8	hy. + stalk.
4	pb.	9	pb.
5	pb. + reprod.	10	d. pb.

TABLE IX.

Number of Piece.	Kind of Structure Regenerated.	Number of Piece.	Kind of Structure Regenerated.
1	dead.	6	pb. + reprod.
2	pb.	7	pb.
3	pb.	8	hy. + stem.
4	hy. + stem.	9	pb.
5	pb.	10	dead.

TABLE X.

Number of Piece.	Kind of Structure Regenerated.	Number of Piece.	Kind of Structure Regenerated.
1	pb.	6	pb.
2	d. pb.	7	hy. + stem.
3	d. pb.	8	pb.
4	d. pb. + reprod.	9	hy.
5	pb	10	dead.

As was the case in the experiments made by Morgan, the results for corresponding pieces of different stems are far from uniform, and it is not possible to determine what kind of a structure will be produced by a small piece from a given region of the stem. It is evident that the power to form either complete or double structures is present throughout the stem, and just what conditions are necessary to produce certain structures have not, as yet, been fully determined. Morgan has suggested that possibly the factors in determining the kind of regeneration are (1) the smallness of the piece, (2) the differences in the region of the original stem from which the pieces came (this factor had been previously suggested by Driesch), (3) the age of the piece, as the younger the stem the more likely it would be to form incomplete structures.

According to this set of experiments short pieces, no matter from what part of the stem they are taken, are more liable to produce proboscides than to form hydranths. When the latter structures appear they are usually produced by the more proximal pieces of the stem, the distal end of the stem showing a great tendency to produce incomplete structures. These results are very similar to those obtained by Morgan on *Tubularia mesembryanthemum*.

In order to ascertain whether the double structures that are so often obtained in such experiments are produced because the small pieces of the stem are open at both ends and not because there is insufficient material in the piece to produce a complete hydranth, Morgan tied one end of a short piece with silk thread, and found that, under these conditions, double structures are never produced. Later he planted short pieces of stems in rows in sand so that one end was buried and the other freely surrounded by water. In two instances only was a double proboscis formed, in all other cases single structures, either incomplete or whole, more often the latter were produced.

In repeating these experiments of closing one end of a short piece of the stem of *Tubularia* in order to ascertain the effect on the kind of structure produced, the following method was used: Shallow, flat dishes were covered on the bottom with a layer of paraffine about one fourth of an inch in thickness, and then, with

the blunt end of a large needle about the diameter of a tubularian stem, rows of holes were made in the paraffine about 0.5 mm. in depth. The dishes were filled with water and the long pieces of stems were put in them and cut into consecutive pieces about 1 mm. in length. One end of each piece was then inserted in a hole that was just large enough to receive and hold it upright. This method has the advantage that the inserted end of the piece of stem is in contact with the paraffine and cannot become free if the experiment is properly done. The results of this series of experiments are summarized in the following tables in which the abbreviations used are the same as those previously employed.

TABLE XI.

Number of Piece.	Structure Produced.	Number of Piece.	Structure Produced.
1	pb.	5	dead.
2	pb.	6	pb.
3	pb. + reprod.	7	dead.
4	dead.	8	pb.

TABLE XII.

Number of Piece.	Structure Produced.	Number of Piece.	Structure Produced.
1	pb.	5	pb.
2	pb.	6	pb.
3	hy.	7	pb.
4	dead.	8	dead.

TABLE XIII.

Number of Piece.	Structure Produced.	Number of Piece.	Structure Produced.
1	pb.	5	dead.
2	dead.	6	pb. + reprod.
3	d. pb.	7	pb.
4	dead.	8	pb.

TABLE XIV.

Number of Piece.	Structure Produced.	Number of Piece.	Structure Produced.
1	hy.	5	dead.
2	pb.	6	dead.
3	pb.	7	pb.
4	pb.	8	dead.

TABLE XV.

Number of Piece.	Structure Produced.	Number of Piece.	Structure Produced.
1	pb.	5	pb.
2	pb.	6	dead.
3	pb. + reprod.	7	dead.
4	pb.	8	dead.

TABLE XVI.

Number of Piece.	Structure Produced.	Number of Piece.	Structure Produced.
1	pb.	5	pb.
2	pb.	6	pb.
3	pb.	7	pb.
4	hy. + stem.	8	dead.

TABLE XVII.

Number of Piece.	Structure Produced.	Number of Piece.	Structure Produced.
1	pb.	5	pb.
2	pb. + reprod.	6	dead.
3	pb.	7	dead.
4	pb. + reprod.	8	dead.

TABLE XVIII.

Number of Piece.	Structure Produced.	Number of Piece.	Structure Produced.
1	dead.	5	dead.
2	pb.	6	hy. + stalk.
3	pb.	7	pb.
4	pb.	8	dead.

TABLE XIX.

Number of Piece.	Structure Produced.	Number of Piece.	Structure Produced.
1	pb.	5	dead.
2	pb. + reprod.	6	dead.
3	hy. + stalk.	7	hy. + stem.
4	pb.	8	hy. + stem.

TABLE XX.

Number of Piece.	Structure Produced.	Number of Piece.	Structure Produced.
1	pb.	5	pb.
2	pb.	6	pb.
3	hy. + stem.	7	pb.
4	dead.	8	dead.

TABLE XXI.

Number of Piece.	Structure Produced.	Number of Piece.	Structure Produced.
1	pb.	5	dead.
2	pb. + reprod.	6	pb.
3	pb.	7	pb.
4	hy. + stem.	8	dead.

TABLE XXII.

Number of Piece.	Structure Produced.	Number of Piece.	Structure Produced.
1	pb.	5	pb.
2	dead.	6	hy. + stalk.
3	pb. + reprod.	7	pb.
4	pb.	8	dead.

The results of these experiments confirm those obtained by Morgan in every respect, as double structures were produced very rarely, only one being obtained in the entire series of experiments. There seemed to be no distinctive individual differences in the pieces of stem as regards the structures produced. In only one case (Table XIX.) were as many as three hydranths produced, while in the tables given by Morgan for *Tubularia mesembryanthemum*, whole series of pieces from the same stem produced hydranths.

If a comparison is made between the results shown in Tables XI. to XXII. and those shown in Tables V. to X., the most noticeable difference is that a very much greater number of double structures were produced when short pieces of the stem were lying on their sides during the process of regeneration. In both sets of experiments single proboscides were the structures most frequently produced, and very little individual difference could be detected in the stems regarding the kind of structure that they would tend to produce.

The development of small pieces of the stem of *Tubularia* standing on one end is considerably slower than that of similar pieces lying on one side. In the latter case, development takes place in about two days; while in the former case the various structures never appear under three days, and usually not under four or five days. Many pieces, usually those nearer the proxi-

mal end of the stem, die when the pieces stand on one end. This result may be due to the fact that the conditions under which regeneration takes place are not as favorable when the end of a small piece of stem is closed by contact with some foreign substance, as when the piece lies on one side and the cut ends are allowed to close in a normal manner.

BRYN MAWR COLLEGE,
Bryn Mawr, Pa., March 23, 1904.

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RESEARCH SEMINAR OF THE MARINE BIOLOGICAL LABORATORY FOR THE YEAR 1903.

The Research Seminar, begun in 1903, was devoted chiefly to informal reports and discussion of work carried on at the Laboratory. It found abundant support and was continued for some weeks after the regular courses ended.

The range of subjects reported upon contrasts strikingly with that of earlier years, when embryology was the main field of productive research at the Laboratory.

The following is a list of the subjects presented, with brief summaries:

July 13. **The Anatomy and Embryology of Pecten tenuicostatus.** By GILMAN A. DREW.

Drawings illustrating the structure and development of this form were exhibited and points of interest were discussed. Much of the discussion concerned the nervous system, the circulatory system, the formation of organs, and the excessive development of the posterior portion of this animal.

The visceral ganglia, which supply nerves to the greater part of the body, are very complex, and the different structural regions are very well marked. The pallial nerves have taken on ganglionic structure probably because of the many tentacles and eyes on the mantle margin that they supply. The cerebral and pedal ganglia are small, corresponding to the reduced condition of the anterior portion of the body. Octocystic canals opening on the surface of the body are present.

The circulatory system comprises a definite system of blood channels, but they are probably not lined with endothelium, so that there is no sharp distinction between blood and lymph.

July 15. **The Origin and Relationships of the Rock Pigeons as Revealed in their Color-Patterns.** By C. O. WHITMAN.

The wild rock pigeons present two very distinct color-patterns — (1) the chequered type, and (2) the barred type.

Two black wing-bars on a gray ground have always been held to be the more primitive pattern, and birds of this pattern are supposed to represent the typical *Columba livia.*

The form with black chequers evenly distributed over the wing and back, although once named *C. affinis,* as a distinct species, was regarded by Darwin as a variety derived from the two-barred rock, and his opinion has stood undisputed.

It appears from a comparative study of many species of wild pigeons, and from a study of the variations in domestic species, that the relationship is just the reverse : *C. affinis* is the original rock dove, and *C. livia* is the derived type. Domestic pigeons have come from both sources.

Columba affinis, however, is not the most primitive form among the wild pigeons. It was derived from a more ancient type, best preserved in the turtle doves (*Turtur orientalis* and *Turtur turtur*). In the turtle dove type each feather has a dark center and light edge.

The turtle dove pattern is at the same time a general avian pattern.

The turtle type and the rock type coexist in some forms (*e. g.*, *Phaps chalcoptera*).

The two-barred pattern of *Columba livia* was reached in the simplest way by an even reduction of the dark pigment, which would result, at one stage, in leaving remnant spots on the long coverts and the secondaries.

The process of reduction has run in *one direction* in many, if not all pigeons, and present species have reached different stages, varying all the way from a uniformly spotted condition to four, three, two, one or part of one bar, or no bars.

It appears to be impossible to reverse the direction of evolution, and to advance from one or two bars to a complete or even a partial chequered state.

The white-winged pigeon (*Melopelia leucoptera*) has no black spots or bars on the wing in the adult plumage, but unmistakable evidence of their former existence is seen in *structural* imprints still left on many of the coverts, and in vestigial traces of spots in a few of the juvenal feathers.

July 17. **Effects of Light-rays on an Ant.** By ADELE M. FIELDE.

The species used for the experiment was *Stenamma fulvum*, a myrmicid ant. Five queens and about two hundred workers were kept for ten months in each of five artificial nests, one nest roofed with transparent glass, one with opaque glass, one with glass transmitting only red and green rays, and two with glass transmitting only rays of shorter wave-length than blue. These nests were exposed to like temperature, and the ants were fed on the same foods. In all the nests the young passed safely through the egg, the larval and the pupal stage, and reached active life, proving that the cause of the usual hasty withdrawal of the inert young from daylight does not lie in any injury by any of the rays of the spectrum.

The ants are blind to all rays of light other than the ultra-violet, and they avoid the ultra-violet rays in proportion to the intensity of the illumination. They often congregated with their young in the spots where the illumination from the red and green rays was most intense. Orange glass which excludes most of the ultra-violet rays may be used for roofing their artificial nests, and then the ants may be studied with the certainty that they behave as if they were in darkness.

At the end of ten months marked ants from each of the five nests were introduced into each of the other four nests, where they were amicably received, and it was thus determined that exposure to any ray of light in the spectrum does not affect the odor whereby the ants recognize one another.

July 20. **Further Experiments in the Embryology of the Chick.** By F. R. LILLIE.

First, three cases in which the cerebral hemisphere of the right side was destroyed at an early stage, and which resulted, after farther growth of the embryo for four or five days, in displacement of the wing rudiments of the opposite side. This displacement was the same in all cases and was never found in normal embryos. The conclusion was that there is some trophic relation between the higher brain centers of one side and the embryonic tissues, especially muscular tissues, of the opposite side; this be-

ing expressed in the case under consideration by the abnormal growth of the wing. The sections of these embryos show that the parts of the brain posterior to the cerebral hemispheres on the defective side were less developed than on the uninjured side, owing to the absence of descending tracts from the cerebrum of that side. This defect disappeared in the region of the medulla, from which it may be concluded either that the tracts had descended no farther, or that approximately half had decussated. The trophic effect, if any, would be indirect, through the intermediation of the motor neurons of the chord. Subject still under investigation.

A second series of experiments was made involving destruction of the hind end of the embryo, showing, first, that there is no regeneration, and second, that the uninjured embryonic parts developed precisely as they would have done in a normal embryo. Thus, if but a single leg-somite remained, a rudiment of the leg was formed in a developing embryo; but if all the leg-somites were destroyed no rudiment appeared. Absence of the allantois was noted in such embryos.

Other modifications of internal organs were described.

July 22. **Variation and Selection in Saturnid Lepidoptera.** By HENRY EDWARD CRAMPTON.

An account was given of a study upon variation and its relation to elimination in *Philosamia cynthia*, as well as of additional studies which have been prosecuted during the past five years upon the same, and other problems in the case of *Cynthia* and other saturnid moths. The first points determined were: (1) That when normally formed pupæ which died before metamorphosis, were compared sex by sex with pupæ which lived through the metamorphosis, the two groups were markedly different in several characters, as regards the typical condition as well as the variability with reference to such typical condition. Thus pupal elimination and variation were shown to be related. (2) A comparison of the pupæ which metamorphosed perfectly with those which formed more or less imperfect moths revealed a second period of elimination which again proceeded hand in hand with variation. Thus "secular" and "periodic" selection, so-called

by Pearson, were proven for *Cynthia* of this year (1898–1899). Annual series of the same species exhibited the same phenomena. Three lots of *Cecropia* have been likewise examined, in much greater detail (28 characters), and these also show both kinds of selection.

An enquiry into the occurrence of reproductive selection grew naturally out of the foregoing. Two annual series of *Cynthia* (more than two hundred matings) and two annual series of *Cecropia* (130 and 125 matings respectively) have afforded the basis for the following conclusions: Pupal characters of mating males, or females, when compared with similar characters of the non-mating males, or females, prove to be different in type and restricted in variability. Thus a third period of selection is shown to be correlated with variability.

In discussing the nature of the selective processes, reasons were given for regarding the correlations between the several characters as the real bases for the action of eliminating processes, and not the individual characters themselves.

Further studies, now in progress, were briefly described. These deal with the phenomena of correlation between characters of the individual in its successive larval, pupal and imaginal conditions; with inheritance in pure breeds, and in mixed breeds; and with the correlation of certain physiological reactions with structural characters.

July 24. **White Feathers.** By R. M. STRONG.

The few references in the literature of feather coloration to the causes of white in feathers state that the whiteness is due to the presence of air in the feather substance. This is misleading, for the larger proportion of the white effect is produced by the barbules which do not have air-spaces of significant size. The barbules are white for the same reason that powdered ice or glass and other transparent substances in a fine state of division appears white.

July 24. **Nervous Regulation of the Heart of Venus Mercenaria.** By R. A. BUDINGTON.

The details of the nervous control of the heart of vertebrates have been worked out in more and more minuteness since the time when

attention was first called to the matter by the Weber brothers in 1846. A similar relation of the nervous system and heart has been shown to hold among the invertebrates also, notably through the work of Conant and Clark on arthropods, of Ransom, Straub, and Yung on mollusca. The last-named worker has described inhibition of the heart of lamellibranchs on stimulation of the visceral ganglion, but no graphic records have been published illustrating experimental investigations of this kind.

In this seminar experimental work on the heart of *Venus mercenaria* was described, and kymograph tracings exhibited, which seem to warrant the following conclusions:

1. Normal rate and character of the heart-beat varies widely with different individuals.

2. Partially exhausted hearts show extreme irregularities.

3. Electrical stimulation of the visceral ganglion causes arrest of the heart.

4. Stimulation of the cerebral ganglion produces no effect.

5. Stimulation of nerves passing from the visceral ganglion to the heart gives results comparable in every way to those obtained from stimulation of the *vagus* in the vertebrates, viz: long after-effects of strong stimulation, and typical escape from weak stimulation.

6. No evidence of acceleration was ever present.

Definitely localized cardiac organs are found in no group of animals generally considered lower than the lamellibranch molluscs. It would therefore seem that, notwithstanding one or two doubtful exceptions, cardiac muscle, wherever found, does not perform its functions entirely independent of inhibitory influences of the central nervous system.

July 27. **The Relation Between the Solution Tension and Physiological Action of the Elements.** By ALBERT P. MATHEWS.

As already pointed out by Loeb and the author, there is a relationship between the valence of an ion and its physiological action. For the motor nerve anions with three charges are somewhat more than three times as powerful stimulants as anions with one charge. There are, however, for other tissues wide divergencies from this rule, particularly for the cathions. For ex-

ample, mercury and copper are enormously more powerful than the bivalent alkaline earth metals; and hydrogen with one charge is more active than other univalent metals. The author suggested that this divergence from the theory probably meant that it was the motion of the valence or charge which ultimately determined its action and that the velocities or orbits differed for the charges attached to different elements. Dr. Stieglitz suggested that the affinity of the atom for its charge might vary and account for these discrepancies. It occurred to the writer that this affinity might be represented by the solution tension of the element. The more easily the element is separated from a solution of its ions, the less is its affinity for the charge it carries as an ion. I have accordingly compared the poisonous action of the metals and negative elements with their relative solution tension as given by Nernst, using *Fundulus* eggs as test objects. The least concentration of the solution of the chlorides of the different metals which would just prevent the formation of an embryo was determined.

The result showed a marked inverse ratio between the solution tension and poisonous action. Potassium with its great solution tension is almost the least poisonous; silver with a very low tension is the most poisonous. The other metals arranged themselves in proper order, except that ferric iron, zinc and cadmium were more poisonous than their position in the list of metals would indicate. This discrepancy is probably due to the fact that the solution tension is but a poor measure of affinity between the charge and the element. The anions arrange themselves in order, those parting with their negative charges most easily being most poisonous.

The correspondence is so close as to indicate clearly that the affinity between the electric charge and the atom is a powerful factor in determining physiological action, and that the less strongly the charge is held, the more powerful is the action of any ion.

Experiments were also tried demonstrating that the action of any cathion is modified by the action of the anion; and that of any anion is modified by the action of the cathion. There is hence an antagonistic action between anions and cathions and the

physiological action of any salt is equal to the sum of the actions of the two ions.

In the toxic and antitoxic action of salts as described by Loeb, both the anion and the cathion are of importance. There is no simple relationship of antitoxic action between monovalent and bivalent cathions.

July 31. **The Cranial Nerves of Squalus acanthias.** By O. S. STRONG.

The object of the work is to confirm, using serial sections, the partial analysis of the cranial nerves into their components accomplished by means of gross dissection by previous investigators, and to extend that analysis further. The components are found to be the same and to have the same general typical arrangement as in other vertebrate types. The trigeminus is purely "general cutaneous." The facialis has four roots: two lateral line roots (R. ophthalmicus superficialis, buccalis, mandibularis externus, etc.) distributed to the canal and ampullary organs of the head, one communis root to the mouth (R. palatinus, mandibularis internus, etc.) and one motor root. The post-auditory roots are the lateral line root, including also a small separate root to one or two canal organs *via* the glossopharyngeus, a series of communis roots and a series of motor roots. The communis roots are distributed into the pre- and post-branchial and visceral branches, innervating the branchial cavities, pharynx and viscera.

July 31. **A Case of Almost Complete Absence of the Left Cerebellar Hemisphere in the Brain of a Child Three Years and Four Months Old.** By O. S. STRONG.

The external appearances have been reported elsewhere (*Journ. Comp. Neur.*, Vol. XI., No. 1). The sections show the following principal abnormalities: absence, usually complete or nearly so, of the right olive and the cerebello-olivary fibers connected with it, of the left restiform body, of the transverse pontine fibers to the left cerebellar hemisphere, of the right *nucleus pontis* and of the left superior peduncle. The left *formatio reticularis* contained more longitudinal fibers than the right. The left lemniscus showed some degeneration and the left *corpus quadrigeminum anterior* was much smaller than the right.

July 29. **Hybrids from Wild Species of Pigeons, Crossed inter se and with Domestic Races.** By C. O. WHITMAN.

The species thus far employed with some success in crossing are the following:

FERAL SPECIES:

1. Oriental turtle (*Turtur orientalis*).
2. European turtle (*Turtur turtur*).
3. Chinese turtle (*Spilopelia*[1] *chinensis*).
4. Surat turtle (*S. tigrina*).
5. Blond ring dove (*Streptopelia*[2] *risoria*).
6. White ring dove (*S. alba*).
7. Oriental ring dove (*S. torquata*).
8. Red ring dove (*S. humilis*).
9. Passenger pigeon (*Ectopistes migratorius*).
10. Mourning dove (*Zenaidura carolinensis*).
11. White-winged pigeon (*Melopelia leucoptera*).
12. Wood pigeon (*Columba palumbus*).
13. Guinea pigeon (*Columba guinea*).

DOMESTIC RACES:

14. Homer (*Columba tabellaria*).
15. Fantail (*Columba laticauda*).
16. Tumbler (*Columba gyrans*).
17. Archangel (*Columba illyrica*).
18. Mondain (*Columba admista*).
19. Chequered rock (*Columba affinis domestica*).
20. Owl-rock hybrid (*C. turbata* × *C. livia*).

The more important hybrids and their parent species were exhibited, and the importance of *known ancestry*, for definite results, was clearly demonstrated.

With a few exceptions, the hybrids were remarkably close intermediates. Reciprocal crosses gave like hybrids.

Several series of fertile hybrids have been obtained. The most remarkable case was a male hybrid between a male chequered rock pigeon (*C. affinis domestica*) and a female oriental

[1] Sundev, *Math. Nat. Av. disp. Tent.*, p. 100, 1872. The species 1–8 are usually included in the genus *Turtur*. The *Streptopelias* and *Spilopelias* are both sufficiently distinct for generic rank, and it is convenient to deal with them as genera.

[2] *Bp.-Comsp. Av.*, II., p. 63, 1854.

turtle dove (*Turtur orientalis*). The offspring of this hybrid, mated with the domestic pigeon, exhibited segregation; but neither in the first nor the second generation were there "dominants" and "recessives" in the Mendelian sense.

No support was found for the so-called "principle of pure germ-cells" in hybrids. Segregation is probably never complete; and in some cases at least the intermediate character seems to be permanent.

August 3. **On the Presence of Specific Coagulins in Animal Tissues.** By LEO LOEB.

It has been known before that extracts of many animal tissues have an accelerating effect upon the coagulation of the blood. It can, moreover, be shown that there exist in animal tissues specific substances which act specifically upon the blood of animals in which they are found, or upon the blood of related species. I have previously found these specific substances in mammals, birds, reptiles and amphibia. Further investigations show that they exist also in invertebrates. The muscle of the lobster acts more strongly upon the blood plasma of the lobster than upon the blood-plasma of the blue crab; the muscle of the blue crab acts more strongly upon the blood-plasma of the blue-crab than upon the blood-plasma of the lobster. Pieces of muscle of other animals than arthropods, which have so far been tried, are without effect upon the blood-plasma of the lobster.

For vertebrate blood there exist non-specific or less specific substances like peptone. Similar substances can also be found in certain animal tissues. The specificity of blood-coagula of vertebrates could not be demonstrated among vertebrates, although they become specific if used with invertebrate blood upon which they do not act at all.

Non-specific or less specific substances exist also in invertebrate tissues, as for instance in the ova of *Arbacia* and other animals. They are able to cause a coagulation of the blood of invertebrates which are not closely related.

The origin of these substances, which are peculiarly useful, will probably have to be explained by a process of auto-immunization. This explanation is suggested by the great similarity be-

tween the specific coagulins and substances derived by artificial immunization.

August 5. **The Retinal Nerve-endings in the Eye of Pecten.** By IDA H. HYDE.

Although the more important methods of staining were tested, none proved so satisfactory as the methylin blue method of Bethe, which was used in a somewhat modified form.

The chief facts regarding the nerve-structure of the eye are as follows: There are two kinds of nerve-tissue. The first is an efferent, or, possibly, a trophic nerve-system, the fibers of which form the side-branch of the optic nerve, and are continuous throughout the peculiar twine-cells to their terminations on the supporting as well as on the nerve-cells in the eye. These fibers penetrate the eye on one side and form a single layer of large unique structures called by the author "twine-cells," as they have the appearance of fibers much coiled in the form of balls of twine. This layer of twine-cells lies between the lens and the retinal disc and on the disc. From these cells fibers extend to other twine-cells, to the tapetum and argentia, as well as to the supporting cells of the retina and as far as the rods.

The fibers are very fine, have a beaded appearance, and are in every respect different from the sensory nerve-fibers, which form the second kind of nerve-tissue.

These sensory nerve-fibers arise as modified nerve-cells, and form the rods which connect with long bipolar cells by means of small dendritic processes. The bipolar cells join the large marginal ganglia by means of nerve-endings in the ganglion. The marginal ganglia form a border of large ganglia cells around the retinal disc, the axones of the ganglia passing in the form of a cup-shaped case over the eye to form the optic nerve. The sensory nerve fibers and cells are surrounded by a hyaline sheath, which is absent in the efferent fibers.

August 5. **The Static Function in Gonionemus.** By LOUIS MURBACH.

The movements of the medusa *Gonionemus* would indicate that it has a definite sense of equilibrium, and some preliminary experiments confirmed this view. To localize this sense experiments

were made to change the center of gravity by weights, etc. These were followed by the removal of different organs, the tentacles, the manubrium and the gonads, but without producing any marked disorientation. It seemed, then, that the otocyst organs to which this function is usually ascribed were thus shown to be active.

At first, solution of the otoliths was attempted with various acids; but it was found that all acids tried, if strong enough to dissolve the otoliths, also killed the animals. Then the vesicles were punctured, putting the otocysts out of function, but in the light of all the experiments there was no definite disorientation, except when the velum was severely mutilated. While this was not a proof that the otocyst organs do not function as the principal organs of equilibrium, the latter observation suggested that equilibration in this medusa is, to a large extent, to be ascribed to "muscular sensation." Further experiments were finally made, cutting away the margin of the bell, including the bases of the tentacles and the otocyst organs. Intermediate portions of the margin were left until healing had taken place; then the remaining portions of the margin were cut away and the animal tested. Although the medusa was more or less imperfect from the operation it was not seriously disoriented but moved in definite directions, including swimming to the surface of a shallow dish of sea water and turning over, also lying with the opening of the bell turned up.

From all the experiments it seems to follow that the otocyst organs serve very little in the equilibrium of the medusæ, and that the muscular sensation is probably the principal factor.

August 7. **Nestling and Juvenile Plumages of Sterna hirundo and S. dougalli.** By LYNDS JONES.

The ventral downs of the nestling plumage are wholly white, except the throat, where the tips are dusky-black. All dorsal downs have a dusky-black base, then a tawny area, then a dusky-black area, and many a tawny tip. In the nestling *hirundo* these dusky tips are arranged in mottled pattern, but in *dougalli* in stripes. Both patterns are protective, *dougalli* nesting mostly among grasses, *hirundo* originally on the beach among pebbles and seaweed.

The juvenile plumages of the two species present the same general pattern, but differ in detail. In both the ventral plumage is essentially pure white, *dougalli* showing a faint rosy tint. All dorsal feathers are pure white at the base, then, except the remiges and rectrices, which are nearly like the adult feathers, a pearl-gray area, followed by a dusky area, and all feathers with a tawny tip. The inner tertiaries and their lower coverts, and the lower rows of scapulars, have an added area of tawny and of dusky colors. Thus the tawny and dusky areas of the nestling downs are reproduced in the juvenile feather, with the addition, at the inner half of the juvenile feather, of an area of pearl-gray and a white base. The pearl-gray area corresponds in color to the color of the adult feather.

In *hirundo* these markings produce a barred effect, except on the head, which is white at the base of the bill, gradually darkening to black on the crown and occiput. In *dougalli* the outer tawny and dusky areas are parallel to the border of the feather, in the more strongly marked feathers, for fully a third of the length of the feather, and therefore present a more mottled pattern. Some feathers are even distinctly barred with dusky color about their outer third.

The essential pattern of the two plumages is, therefore, a definite barring of each feather on the dorsal surface, and a lack of any marking on the ventral surface. The greatly modified remiges and rectrices closely resemble the adult remiges and rectrices, thus requiring no transition stage, but the rest of the dorsal plumage undergoes a distinct transition from the nestling to the adult, the intermediate, or juvenile plumage, resembling the nestling plumage for its outer half, at least, and the adult plumage for its basal half.

August 7. **The Internal Factors of Regeneration in Alpheus.** By CHARLES T. BRUES.

Alpheus is a small decapod crustacean in which one of the chelæ is larger than the corresponding one on the other side. When one of the larger chelæ is cut off at the base, it has been shown by Przibram, and also by Wilson, that its stump regenerates a chela of the small type, while the originally small one is

remodeled into a large one. Section of the nerve at the base of the small chela inhibits this reversal, wholly or partially.

With regard to the internal factors which induce this reversal it seems at first sight that the nervous system must be the controlling one. Histological examination shows the following facts: (1) Nerves of the right and left sides are not morphologically different except that they branch differently in the two types of claw. (2) During regeneration or remodeling changes occur in their definitive places, *i. e.*, growth does not occur at one end only. (3) The nervous shock of amputation may produce a weakness of the cut side, and also add to the nutriment of the other side of the ganglion, thus inducing reversal. (4) The nerve evidently carries the stimulus to grow, but may be only passive. (5) The cutting of the nerve in the claw may cause a general disease of that organ, such as might be caused by injuring the musculature, and thus prevent perfect reversal.

It appears, therefore, that we must not attribute to the nervous system as much importance in the remodeling as would seem at first sight necessary when it is found that section of the nerve inhibits reversal.

August 12. **The Development of the Vascular System of Ceratodus.** By WM. E. KELLICOTT.

The vascular system of the adult *Ceratodus* shows resemblances to both the elasmobranchs and the amphibia. It was thought that the investigation of its development might throw some light upon the significance of this curious combination. A few of the points of interest which appeared in the course of the study are the following:

The heart develops similarly to that of the frog or *Urodele*, from a pair of folds of the splanchnopleure, the somatopleure forming the pericardium.

The branchial arteries also develop similarly to those of the amphibia. They are four in number and early form continuous passages from the ventral to the dorsal aorta. Later they divide into the afferent and efferent vessels and finally each efferent divides, forming the two efferent branchials characteristic of the adult. The vessels of the hyoid arch are well developed early,

but later disappear. The vessels of the mandibular arch are only slightly indicated.

The veins are arranged symmetrically during the early stages. The arrangement of the cardinal veins is typical. A well-marked subintestinal vessel is present very early; later it disappears in part, and in part becomes connected with the hepatic-portal vein. The vena cava is for a time independent of the cardinal system; later the anterior part of the right posterior cardinal disappears, while the vena cava connects with its posterior section. The pulmonary vein appears very late.

Many of the features of the development of the vascular system are closely similar to those of the Urodela. Some, though not all, of the elasmobranch resemblances appear quite late in the process of development and are preceded by conditions which are typically amphibian. There are, however, typical elasmobranch characters present from the first.

August 12. **The Metamerism of the Nervous System in Arenicola cristata.** By C. P. LOMMEN.

The arrangement of the nervous system of *Arenicola cristata* is definitely related to the annuli forming its somites. A pair of nerves from the ventral cord proceed dorsally between the longitudinal and circular muscles along each of the grooves that separate the annuli. These nerves give off numerous tiny branches, and do not unite dorsally to form rings. In the setigerous annuli there are two additional nerves which are imbedded in the circular muscles, one on each side of the neuropodium. The posterior one divides into two branches, one passing into the gill and the other into the seta-sac. Anteriorly the number of annuli in the somites is gradually reduced from five to two. From the outside of each connective a series of eight nerves is given off, all of which are presumably homologous to the nerves from the cord. This homology has been shown with certainty only in the case of three. Of the remaining five, one innervates the otocyst, the position and muscular connection of which are suggestive of homology with a seta-sac. Fifteen nerves from the inside of the connectives give off some branches to the body-wall and then bend back into the wall of the pharynx, innervating its ventral

and lateral sides, and passing then into the œsophagus. The dorsal wall of the pharynx is supplied by a plexus of nerve-trunks from the brain and the nearest portions of the connectives. The plexuses on the two sides of the body are seldom alike. From the posterior lobes of the brain several nerves pass to the nuchal organ. In the caudal region, the number of annuli in each somite, and with them the number of nerves, may vary from three in the anterior part to nine or ten in the posterior part.

August 14. **The Organization and Orientation of the Ascidian Egg.** By E. G. CONKLIN.

During this summer I have studied the development of three species of solitary ascidians, viz. *Styela* (*Cynthia*) *partita*, *Molgula Manhattensis* and *Ciona intestinalis*, with the purpose of finding out how much of organization can be recognized in the unsegmented eggs of these animals.

In the living eggs of all these ascidians, but particularly in the first mentioned, one can recognize the substance of the ectoderm, the endoderm and at least a portion of the mesoderm before the first cleavage occurs.

The spermatozoön enters at the vegetative pole in an area of cytoplasm free from yolk and in *Styela* a dense mass of orange pigment aggregates at this spot and slowly spreads over the vegetative hemisphere. Subsequently it withdraws to one side of this hemisphere, thus forming an orange crescent which lies just below the equator on the posterior side of the egg. The vegetative pole then becomes slate-gray in color and the animal pole a light gray. The study of the subsequent development shows that all the axes of the future animal are now established and that the slate-gray substance forms endoderm, the light gray ectoderm and the orange crescent the muscular system of the tadpole. In *Ciona* and *Molgula* the crescent is present as in *Styela*, but is nearly colorless, while the substance of the ectoderm and of the endoderm may also be recognized in the unsegmented egg.

An incidental result of this work is to prove beyond question than Van Beneden and Julin were right in their orientation of the ascidian egg and that the polar bodies are found at the ectodermal and not at the endodermal pole, as Castle has maintained.

August 14. **Rhythms of Susceptibility and of CO_2 Production in Cleavage.** By E. P. LYON.

Two years ago the author found that the *Arbacia* egg about fifteen minutes after fertilization is very susceptible to lack of oxygen or to KNC. At other times during the first cleavage it is more resistant. This rhythm of susceptibility and resistance recurs in each succeeding cleavage period.

Further investigation shows that cold acts like lack of oxygen. If the eggs are kept at about 0° C. for a number of hours, those which are placed on ice about fifteen minutes after fertilization are much injured, and may wholly fail to develop, while little harm is done to eggs which have passed the critical stage before being cooled. This rhythm recurs in successive cleavages.

Heating the eggs to 33°–38° C. for a few minutes reveals the opposite rhythm. They are most susceptible at the time of cleavage and are little injured ten or fifteen minutes after fertilization or at corresponding stages in the following cleavages.

The CO_2 output of a mass of eggs is greatest at the time of cleavage. At the time when oxygen is most needed, apparently little CO_2 is produced. This shows that the oxygen, in all probability, is needed for synthetic processes and that the CO_2 is produced by splitting and not by oxidation. The rhythm of CO_2 production can be demonstrated also in the second cleavage.

August 17. **The Voices of Pigeons. I. The Voice of the Ring Dove (Turtur risorius).** By WALLACE CRAIG (demonstrations with the doves).

Nearly five hundred species of wild pigeons are known, and, so far as observation goes, each species has a perfectly distinct and constant set of notes. These voices have had a common origin, and the problem is to discover this and trace the derivation of homologous elements.

The work consists of two parts, a study of the voice in each species, and a comparison of different species and their hybrids. The former may be further divided into: (1) A description of the different notes, the attitudes which accompany each, and their whole significance in the life of the bird; (2) the development of the voice in the young; (3) a history of the seasonal changes in voice and behavior in the adult bird. The first and second of these subdivisions were reported upon in this seminar, and the

main facts presented were as follows: The adult ring dove has only three principal calls, but these have a number of modifications, which, together with many expressive movements, afford a considerable variety of expression. All these modes of behavior seem to be strictly inherited. They develop in the young bird very gradually, and in a definite order which is probably also the order of their development in the race.

August 24. **Some Reactions of Mnemiopsis Leydyi (A. Ag.).** By GEORGE WILLIAM HUNTER, Jr.

Mnemiopsis orients itself with reference to gravity, being negatively or positively geotropic under differing conditions. It has two characteristic resting positions, one at the bottom with the aboral pole upward and one at the surface of the water with the oral pole upward.

In strong and moderate intensities of light it may be first negatively and later positively photopathic; to very weak intensity of light it may be positively photopathic. Some evidences of phototaxis are found under strong light, the aboral end being directed toward the light.

The animal reacts toward a moderately strong constant current (one half to three volts) by turning the aboral pole toward the anode and moving to the cathode. A weaker current may cause orientation without movement toward the cathode.

The action of the "make" and "break" upon muscles and cilia depends upon the position of the electrodes and the strength of the current.

Mnemiopsis is relatively more resistant to decrease than to increase in the temperature of the water. Responses to electrical stimulation under conditions of greater heat than normal show decrease in reaction time up to about 29° C., then rapid increase in reaction time. Responses to electrical stimulation under conditions of decrease from normal temperature show little change in reaction time to about 15° C., then a slow increase in reaction time.

August 24. **The Reaction Time of Gonionemus Murbachii to Electric and Photic Stimuli.** By ROBERT MEARNS YERKES.

This experimental study of the time relations of the neural processes of *Gonionemus* indicates: (1) A reaction time to elec-

trical stimuli of from .6″ to 2.0″ according to the intensity of the stimulus and the position of the organism; (2) a shorter reaction time when the radial canal regions are stimulated than when the inter-radial regions receive the stimulus; (3) rapid fatigue with repetition of the stimulus; (4) a reaction time to photic stimuli of 1″ to 10″ dependent upon conditions; (5) a much quicker reaction to light when the organism is resting subumbrellar surface uppermost (exposed to the light) than when the exumbrellar surface receives the stimulus; (6) a specialization of organs for the reception of photic stimuli; (7) the existence of highly irritable and conductile tissues (nervous system); (8) that excised organs rapidly lose their irritability; (9) that variability of reaction time for comparative work should be expressed in terms of percentage of the reaction time as well as in absolute terms. This relative variability may be called the variation coefficient.

August 24. **The Establishment of "Association by Contiguity" in Hermit Crabs, Eupagurus longicarpus.** By E. G. SPAULDING.

Crabs are naturally positively *heliotropic*. They were taught to react *against* this by feeding them in a darkened portion of aquarium. Coefficient of daily improvement in eight days = 6.00. The darkening screen was removed each time after feeding. After seven days the crabs go behind the screen, when inserted, although no food is there. This proves the existence (*a*) of association between two different stimuli and (*b*) that when one of these, the screen, is presented, the usual effect of the other is internally reproduced. This may be interpreted as *conscious memory*.

August 24. **The Resin Gnat and Three Parasites**: A Study Made in July and August Under the Direction of Mr. Chas. T. Brues. By L. ECKEL.

This study of *Diplosis resinicola* brought to notice three parasites, among a number of additional facts about this insect, whose larval stage is well known to be passed within the lumps of resin that exude from various species of pine, and which pupates within the resin:

1. *Polygnotus pinicola*, a proctotrupid which has been reported as parasitic upon *Diplosis pini-inopis*. It destroys many of the

larvæ of *Diplosis resinicola* in July, twenty transforming in one *Diplosis* larval skin.

2. Two *Chalcis* flies; one a species of *Syntasis*, described now for the first time as *Syntasis diplosidis*, the second as yet undetermined. They destroy many pupæ of *Diplosis resinicola* in early August.

August 26. **On the Artificial Creation of Mixed Nests of Ants.** By ADELE M. FIELDE.

Natural mixed nests of ants have been described, but such nests are always of ants belonging to the same subfamily, and not more than two species of ants ever inhabit the same nest.

There are two ways in which an artificial mixed nest may be created; one is by depriving all its residents of the sense of smell by removing the funicles of the antennæ; the other is by accustoming all the resident ants from their earliest hours to the odor of each kind of ant that is to occupy the artificial nest. If a nest not larger than a watch-glass be made, and one or more ants from each selected colony be sequestered in this nest, within twelve hours from the moment of hatching, these ants will each touch all the others with the antennæ and will thus become accustomed to and unafraid of the odor of species unlike their own.

An ant reared in isolation will not affiliate with any whose odor differs from its own. Its criterion of correct ant-odor having been formed within three days after hatching, it continues hostile through life to all ants whose odor disagrees with its standard. But by the process of ant-education herein indicated, any ant may be induced to live peacefully with those of a different genus, or even of another subfamily.

Several artificial nests were shown in which ants of four genera, or of all the three subfamilies, were living together, and in which young ants of one genus were snuggling the queen of another genus.

Were the ants in the artificial nests set free, their unlike requirements relating to temperature, humidity and food would soon separate them; but it is improbable that these individual ants would ever fight with one another on subsequently meeting, although any of them would fight with ants of other colonies than those in which their early companions originated.